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Production
Analysis
and
Control

Production Analysis

INTERNATIONAL TEXTBOOK COMPANY
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To
the Zemberry family—in gratitude,
and
my son Louis, Jr.—for his first birthday

2-25-64 gift of Mr. A. L. Kahl

Preface

The decade-long squeeze on profits has accentuated the need for a greater understanding of the role that production planning and control can play in enhancing industrial efficiency. In particular, the coordination of interdependent activities, through production control, is brought to light in this integrated approach to production analysis.

This book does not fit into available prototypes because it covers the material in greater depth than survey books, but with less rigor than the mathematically oriented production control texts. Nevertheless, detailed intricacies of planning, control, and decision making are presented. By design, however, certain fringe issues that are not directly related to the planning and making of goods are not covered.

This volume is likely to appeal to the beginning student because the material is evolved slowly. However, it is directed primarily to those interested in a compact but thorough coverage. While space limitations did not permit exhaustive treatment of any specific topic, it is believed that the depth of the treatment is quite adequate to instill a profound understanding. Careful reading of the text material, with occasional reference to source material, and a preparation of selected case problems will furnish serious-minded students and practitioners with stimulating insights into the principles and concepts underlying modern production. Both the text and the case material are so presented that the interrelatedness of various topics, ordinarily treated independently, are readily apparent. This may be a novelty. The author feels that both text and case should bear out the interrelatedness of functional activities.

Even though the author believes in the mathematical approach, the preponderance of problem solving is explained through the logical application of principles. However, the *Appendix* contains ample material for those who prefer the quantitative approach. Cases which accompany each chapter serve as proving grounds for the application of principles. The importance of problem solving through cases and projects cannot be overemphasized in the field of production because it is often the adroitness with which principles are selected and applied which will lead to the proper solution. The adage that the art of application is at least of equal importance as the theoretical knowledge itself is undoubtedly true in production work.

Though this treatise is built around old and proven principles and practices, the forward thrust in production ideas, theories, and practices is by no means neglected. Thus, the last three chapters dealing with automation, operations research, and the humanistic aspects of management give recognition to the dynamic nature of production as a discipline.

Careful attention was given to the selection of cases in an attempt to match case problems with text coverage. As a result, an instructor can supplement the text material either by lecturing or by using well-selected case problems that illustrate the principles. Projects, however, are also provided to be used in lieu of case problems. These projects may be particularly useful in graduate schools. To avoid basing production situations solely on the machine shop, the industrial coverage includes chemical production; meat packing; shirt, steel, furniture, plywood, paper, cigarette, cement, and enamel making; electricity generation; oil refining; cattle and hog raising; and railroad operation, in addition to the traditional fabricating-assembly type production. The usefulness of the case studies is enhanced by the fact that they focus on problems rather than less tangible issues and therefore permit analysis instead of a highly generalized discussion. All cases are authentic even though the names, places, and circumstances under which the problem or problems arose are disguised. Many companies were indeed generous to permit the use of their managerial problems, but did not want to admit publicly that "it" happened to them. Nevertheless, none of the problems are unique, and most companies encounter similar problems at one time or another.

Since production is the result of a system, the principle of specialization and coordination of interdependent activities is emphasized. In a sense, this book represents the Sloan concept of "production through decentralized responsibility, with coordinated control."

The author expresses his thanks to the companies who permitted the use of problems handled originally on a consulting basis. Thanks are also due to Dean James L. Hayes and Assistant Dean William J. O'Brien, both of the School of Business Administration, Duquesne University, for providing time to complete this project; to Professor Judson Neff, University of Chicago, who introduced the author to the case study approach; and Dr. Clarence C. Walton, Associate Dean, Graduate School of Business, Columbia University, who, during the inception of this book, encouraged the author to write teaching material to graduate students having little or no previous acquaintance with production. Though Drs. D. L. Fixler and E. G. Zdinak checked sections of the mathematical appendices, the author is solely responsible for any weaknesses the book may possess and would certainly appreciate any suggestions that would help improve future editions of this book. And I would be less than truthful if I did not convey special thanks to the editorial staff of the International Textbook Company and to Elizabeth Andrews and Virginia Fenton, who cooperated with the preparation of portions of the original manuscript.

Louis J. Rago

Pittsburgh, Pennsylvania
March, 1963

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chapter 1

Laying the Foundations

Production is the lifeblood of the American economy or, for that matter, of any economy. The higher the aggregate value, in constant dollars, of goods and services produced and the fewer the man-hours of labor necessary for that production, the healthier is the national economy. The health of the national economy depends in turn on the health of individual business units. Hence, the central problem of economic well-being is really faced at the plant level.

Since the success of the economy rests ultimately with the individual production enterprise, it is the function of production management, barring monopolistic practices, to keep costs down, keep profits up, and provide the market with goods at competitive prices at the same rate as consumers call for them. In view of the fact that the economy goes up or down with the success of its component parts, management must, of necessity, have the public interest at heart. Although central governments can and do influence the business climate, the capitalistic system, generally speaking, manages itself instead of being managed by a handful of planners who decide what will be produced, and when, to satisfy human needs. Central governments, no matter how skillful, could not possibly be a substitute for the interaction of the decisions of millions of free men and millions of free enterprises.

Let us not go overboard, however, and believe that the principles governing national production are the same as those that apply to single economic units. In general, the better the use that is made of available human and material resources, the higher the overall production and productivity in both the economic and the management sense. But high production in face of slackening demand for a particular company's product may be contrary to the best interest of the individual firm, even though it momentarily serves the interest of the national economy. In discussing production management, therefore, emphasis is on the individual firm, not on national production.

The foremost task of production management is to produce goods at a profitable level and to organize the use of productive resources to that end. Obviously, the success of a company cannot be measured solely with growth statistics, because in order to consider a business enterprise successful, growth in production must be accompanied by at least a corresponding growth in profitability. Hence, growth in production does not of itself imply successful management.

It should now be apparent that success in production must always be measured in dollars and cents, either in costs of production or in profits. Falling costs and rising profits tend to indicate that company resources are used wisely in relation to outside influencing factors such as demand and competition. The fact that the successful enterprise tends to contribute most to the betterment of the economy is merely a happy coincidence. Nevertheless, in predominantly competitive economies, the successful enterprises are usually those that enjoy high labor productivity and contribute most to the national standard of living. In this sense, then, national productivity can hardly be anything but the sum of the productivity of individual enterprises. The ultimate source of the nation's productivity is, accordingly, always the individual firm.

To see the fundamental difference between the single enterprise and the economy as a whole, it is necessary to analyze the method generally used to measure production and its degree of success. Individual production enterprises appraise results by comparing the profits of similar periods. They use the cost as a criterion to measure improvement or deterioration. If the same result is achieved with lower cost, the conclusion is that efficiency has increased. The success or failure of an individual enterprise is, therefore, frequently measured in terms of efficiency, which is merely the ratio of the results of two comparable production periods. If in one year 100 output units are produced at a cost of $100 as compared to a cost of $200 in the preceding year, the efficiency ratio 1:1 has changed to 0.5:1, indicating that efficiency has increased.

Within a single enterprise, efficiency is the aim; but in considering the economy as a whole, it is customary to speak of productivity. National productivity is expressed in nationwide production, in dollars, divided by the man-hours of labor that produced it. When more is produced with fewer man-hours of labor, national productivity has improved. This also implies that the national standard of living has increased, because we as a nation had to work fewer hours to be able to enjoy more goods. Obviously, dollar value is used to calculate both productivity and efficiency. For that reason, it is not unusual to hear someone speak about productivity and efficiency in the same breadth.

Although efficiency and productivity are indeed related concepts, management must of necessity be concerned mainly with efficiency. If management wants to improve its overall production, it must essentially improve the efficiency of its operations. Collective figures show how the economy is doing, but decisions based on them cannot be very reliable when it comes to running an individual plant.

To show why the terms "efficiency" and "productivity" are not necessarily interchangeable, let us consider a case that illustrates their fundamental difference. Automation might raise production per man-hour of labor, but unless the additional output can be disposed of profitably, automation might be considered a failure from the business point of view (see Chapter 14). Since excess production can be sold only at a sacrifice, the total cost must be deducted from total revenue to find the profit. If the remaining profit is lower with automatic production methods than it was with the earlier production methods, efficiency has actually been decreased by converting to automated production. It is therefore conceivable that a decrease in the total and/or unit costs of production can still be accompanied by a decrease in total profits. Thus, neither output in itself nor productivity in itself necessarily implies successful management. The best yardstick of managerial success is always the size of cost and the size of profit in comparable production periods.

Efficiency is, in general, measurable by costs, but at times this measurement may not be quite accurate. Even though production management has not raised profits or output—or, conversely, has not lowered costs—it may have increased efficiency by turning out goods of higher quality at the same cost and price.

So far, we have emphasized that production management must, under all circumstances, aim for efficiency. In the economic sense, however, it is conceivable that a decision made by an individual company might have a detrimental rather than a favorable effect on the national productivity. The company might, for example, elect to endure a long and costly strike rather than agree to undesirable terms. Even though a strike is bad as far as the economy is concerned, the company might benefit in the long run, despite momentary losses at the time of the strike. But, since the individual firm is always an integral part of the economy (that is, all firms collectively), efficiency increases achieved by a majority of firms tend also to raise total—that is, national—productivity. While in a competitive economy no individual enterprise can always be altruistic in regard to the country as a whole, most enterprises, simply by worrying about their own efficiency and profitability, do tend to contribute to economic health.

What can production enterprises do to increase their efficiency? The preceding paragraphs suggest that management must keep costs down. Low-cost operations, everything else being equal, mean effective utilization of the factors of production. The fewer the man-hours of labor spent on producing an item, the lower the labor cost of the item. If the hours of work have been lowered, the tools of production have also been used for a shorter time. This might then mean that capital costs have fallen in proportion to the decrease in labor costs.

The main task of production management, then, is to decrease both labor and capital costs. But although proper planning and execution of production can increase efficiency of labor and capital, it should not be concluded that production management need not try to reduce the costs of acquiring and storing materials. We merely state that excellent production management tends to manifest itself primarily in lowering labor cost and capital cost per unit of output sold.

In this context "production management" refers to managerial activities that always aim at raising the efficiency of the company's operations. Every production decision must therefore meet the test of efficiency. Since there are usually alternative ways to solve any production problem, that alternative selected should always be the one that will lead to optimizing the costs or, if cost is secondary to some other criterion, to improving things by that criterion.

There may be situations in which speed and expediency are the essence of the decision; instantaneous decision may be the most desirable course of action. In most situations, however, guessing and haphazard action tend to be heavily penalized by lower output, lower profit, or higher costs. Since most wise actions must be based on careful plans, it follows that effective production management largely depends on the care with which production plans are worked out. Every method, every alternative solution, and every decision must be carefully evaluated. Very often, plant management is forced to act not only fast, but also on the basis of incomplete knowledge. Even then, the action must take account of both probability factors and costs and be made as scientifically as possible.

By meeting the test of efficiency, it is implied that decisions must be assumed to be correct at the outset. How can one be sure, however, that the production decision is correct in every respect? Evidently, the real test is profitability—always a retrospective criterion. If quantitative data were available, a preauditing of the outcome of production decisions would be possible, though not always feasible. Many factors which must be taken into consideration are, however, not readily available for a quantitative analysis in useful form. Nevertheless, there are ways and means to look upon the various elements that constitute the core of the decision in quantitative terms. For example, if the output during the normal working day is inadequate, the differential for overtime work represents a higher labor cost. By converting time into its monetary equivalent, we can deal with it as a quantitative factor. Similarly, the cost implications of the size of the production lot can be reduced to quantitative analysis by comparing the cost equivalent of the setup time per unit of output at different output levels with the storage-associated costs on that part of output which is in excess of current needs.

Whereas most quantitative analysis is based on costs and profits, intangible factors must often be considered. At times, the latter may alter ultimate managerial action. Consider for example, an innovation that would very likely lead to lower costs. Even though the new method might promise an increase in profits, it might be postponed or decided against because of qualitative changes associated with it. If there are uncertainties that might conceivably lead to lower demand and less aggregate profit in the long run, those uncertainties must somehow be taken into account. Or suppose that the innovation implies sizable savings in labor cost but that those very savings might cause a strike. Even though the expected savings in labor costs might be substantial, without due consideration to the probability and cost of a strike, they are not a reliable measure of long-run efficiency. That it is difficult to measure "qualitative" matters quantitatively goes without saying.

In summary, one should always keep in mind that management involves the making of a never-ending series of decisions. The results will depend on the thoroughness with which the plans leading to the decision were developed. In this planning process all sorts of cost and other data, both quantitative and qualitative, will have an important part. They will, in the final analysis, show production management which of several alternative possibilities for action is likely to result in the greatest efficiency and profitability in the long run. Thus, profits and costs are always the ultimate criteria of measurement, even though the separate considerations may deal with time, capacity, quality, or some other factor; possibly an intangible factor.

HISTORICAL NOTES

Modern industrial production is the result of centuries of experiment. Although machine technology plays an extraordinary role, the process of producing goods effectively is mainly a matter of applying the principle of specialization. Both laborsaving devices and the tendency to specialize have increased productivity of labor and contributed to a rapid acquisition of material wealth.

Although industrial development finds its roots in ancient history, the wealth modern nations possess is of comparatively recent origin. Ancient industrial evolution moved at a snail's pace; modern industrial development proceeds like a kangaroo. It has been said that industrial development during the last two centuries was greater than during the entire preceding time. This should not be taken to mean that the influence of ancient production is insignificant. Early industrial development was not spectacular, but its influence has been considerable.

Although in present-day production we use methods different from those of our ancestors to accomplish the same goal, namely, creating tangible goods, the basic production concept has not changed. The only innovation is that we have changed the methods of production by applying our greater technical knowledge.

There is no single reason why production methods took a revolutionary turn 200, instead of 500 or more, years ago. We can speculate that the immediate reasons were technological. Nevertheless, they might have been the improvement of overall knowledge and education or merely certain significant changes in society. The fact is that the changes which took place in production methods were caused by a number of things.

Even though production is as old as the human race, the production of today appears to be different from its predecessor. Today machinery plays a paramount role; in the past, labor was the important factor. Yet, any statement claiming that machinery has become more important than labor must be accepted with some degree of doubt. What has happened is that production considerations tend to center today around the machine rather than the man. Even this generalization might prove to be false, because a close look at our plants and factories indicates that labor still calls the tune.

Although the discovery of machinery can be considered the main cause of the industrial revolution,[1] industrial production is still based primarily on excellence of organization, and organization always refers to people. Somehow it must be recognized that man as organizer plays and will always play the most important role in production.

In an attempt to trace the fundamental principles which govern modern production, we must look back not only to the industrial revolution but beyond. Ancient civilizations carried out large and small production projects. It is they, and not we, who developed the governing principles. Organization is the basis of production, and it should not be forgotten that we learned the principles of organization from ancient civilizations. Indeed, the application of the theory of organization, which was known to Moses, coupled with an extensive use of equipment, made extraordinary headway possible.

What we have done is improve on that which others started far back in history. The marvels of antiquity amply demonstrate that ancient production was excellent in its own right. The Chinese Wall, the pyramids, palaces, and temples, to say nothing of many ordinary household objects, indicate that production has existed for years immemorial. While looking at the products of the ages, we must recognize that they required production skill, management know-how, and technology. Even though we would consider ancient production methods to be primitive, in fundamentals they resemble those of the present day.

What has been done since the industrial revolution? Basically we have improved upon everything which the generations before us developed. We have discovered more raw materials (land), developed and improved the use which we can make of human skills (labor), and improved upon original designs of tools (capital). We have also improved upon management methods and principles used in production. As a result we are able to produce more and better goods today.

THE INDUSTRIAL REVOLUTION

At the end of the eighteenth century the time was ripe for true industrial production. At the time that the first immigrants were settling America, the Italians, French, and British were working on all sorts of inventions. One of the most significant was James Watt's steam engine (1765), which successfully operated a pump in a coal mine. When it was applied to driving textile machines, the way was opened to multiplicity of industrial uses. While these developments belong to the eighteenth century, it was the nineteenth century which became the most important to technological development. At the beginning of the nineteenth century, all sorts of production equipment were designed, and at the close of the century electric power was introduced to drive it. There was then a need for venturous and skillful men who were willing to build factories which could make use of these machines.

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[1] The period at the end of the eighteenth century in which changes in the methods of production were so numerous and drastic that the name "revolution" was given to it.

The industrial revolution had a slow start in America, primarily because the American colonies did not become independent until shortly before the turn of the century. Yet, when industrialization overcame inertia, domestic progress was faster here than it was in Europe. The main reason for this was probably that old equipment was not as common here as abroad and the problem of scrapping it was not as severe. As a rule, the best machinery that the need warranted was installed.

American Industrial Development

After a slow start, American industrial progress was phenomenal. This may have been due to the generally favorable economic conditions. Settlers were venturous and diligent people; natural resources were abundant; and skilled labor was scarce. To counterbalance labor shortages, the use of equipment became increasingly popular. As a result, within a short period of time production increased by leaps and bounds. Even so, the early development was slow in comparison with subsequent progress.

A hundred years ago the average American worked 70 hours a week and primarily used his muscles to do the work. He produced approximately 27 cents worth of merchandise an hour. Today he works some 45 hours per week, uses little of his physical strength, yet produces nearly $2 worth of goods an hour in terms of the 1860 dollar. It would be misleading, however, to believe that the twentieth-century labor became so skilled that it alone caused this phenomenal increase in output per man-hour of labor. Actually, mechanization, the extensive use of capital equipment, and an added measure of managerial skill, rather than diligence, have caused this unusually significant rise in productivity. That American industry has succeeded in steadily raising productivity has made it possible for us to consume increasingly more with the passage of years. This is what we mean by the rising standard of living. Indeed, one can justly say that the standard of living of the American is higher than that of most men.

When we compare the present rate of production with the 1860 rate, we can say with some satisfaction that we live considerably better and more comfortably and enjoy a greater amount of leisure time than our ancestors. Thanks to the availability of modern equipment, modern industry can produce faster, cheaper, and better than could industry of the past. Furthermore, high productivity has made personal incomes correspondingly higher and working conditions better.

The industrial revolution only started our industrial growth. Whereas, on the average, our total production increased at an annual rate of 3%, the actual output per man-hour increased only 2.3%. The difference came from surplus output attributable to the growth in the labor force. The rise was by no means a steady one, but fluctuated between 1 and 4%. It was, for instance, in the period of 1947 to 1953 greater and in 1956 lower than the normal rate of growth. The record-breaking growth stood in 1959 at $479 billion, up some 8½% from the previous high of $442 billion recorded in 1957 and 1958. Assuming the normal rate of long-term growth, it is conceivable that total production, measured in dollar value of all goods and services produced, will exceed $725 billion in 1975. This compares with $479 billion in 1959, $500 billion in May, 1960; $522 billion in 1961; and about $555 billion in 1962 with a projected $600 billion, or close to it, for the year at the time this is being written in 1963 (see Fig. 1-1). We could say that the great discovery of the industrial revolution responsible for this growth is that tools, equipment, and electric power can, with a carefully planned utilization of all other factors of production, increase the output per man-hour of labor.

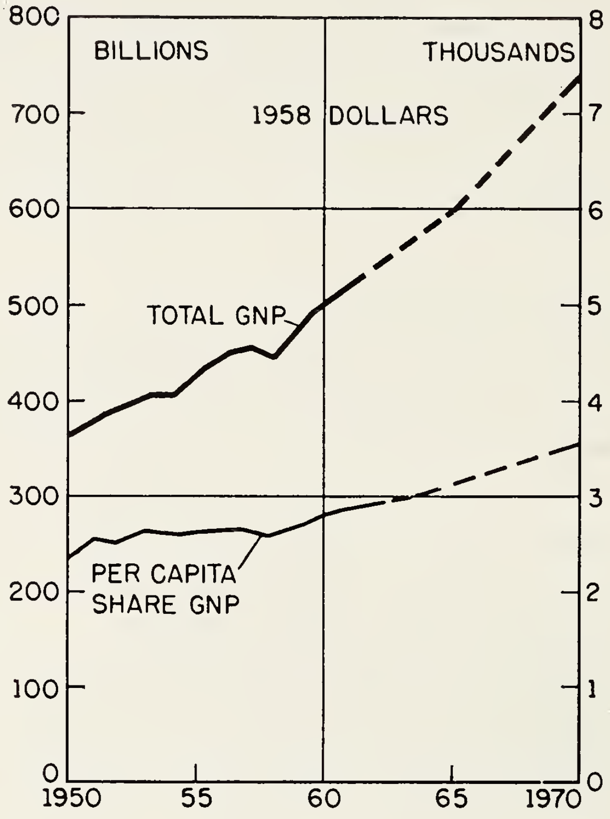

FIG. 1-1. Gross national product 1950-1970. (Courtesy of United States Department of Labor.)

While this economic process goes on, it is possible, depending on economic forces, to raise wages and, because production costs are lower, also reduce the prices of the goods produced. Hence, the industrial revolution proved that the utilization of equipment is inherently related to productivity.[2] This will be of considerable importance during subsequent discussions of industrial production. Whereas Table 1-1 indicates the average annual rate of change in output per man-hour in the total private economy from 1909 to date,[3] Table 1-2 shows the indexes and related data from 1947 to 1961.

TABLE 1-1

AVERAGE ANNUAL RATE OF CHANGE IN OUTPUT PER MAN-HOUR IN TOTAL ECONOMY

Years in which change occurred	Length of period, years	Direction of change in productivity	Average annual rate of change in productivity, per cent*
1909–1912	3	Up	+1.2
1912–1918	6	Down	−0.2
1918–1926	8	Up	+3.3
1926–1933	7	Down	−1.1
1933–1945	12	Up	+4.5
1945–1947	2	Down	−0.8
1947–1953	6	Up	+4.1
1953–1956	3	Up	+2.6
1956–1957	1	Up	+3.4
1957–1958	1	Up	+1.4
1958–1959	1	Up	+4.1
1959–1960	1	Up	+1.7
1960–1961	1	Up	+2.6
1909–1960	51	Up	+2.3

* The average annual rates of change were calculated by the compound-interest method from the indexes for the first and last years of the period covered.

NOTE: Output per man-hour, as the Bureau of Labor Statistics interprets it, refers to the constant-dollar value of goods and services in relation to the hours of all persons, including the man-hours of proprietors and unpaid family workers as well as wage and salary employees. Thus, the output concept is comparable with that of gross national product. The figures in Table 1-1 merely indicate the output in comparison with the man-hours needed to attain it. The percentages indicating the change in productivity do not, however, reflect the specific contributions attributable either to the labor, capital or other factors of production, such as the improvement in materials and management know-how. Thus, the percentages measure the combined effect of a number of interrelated influences, such as skills of workers, managerial skill, improvements in technology, capital investment per worker, utilization of plant capacity, layout and flow of material, the use made of substitute and lower-priced materials, and labor-management relations.

PRODUCTION

Production is the activity of making tangible goods. Whether these goods are to be sold or used by the producer himself is immaterial. This definition is somewhat narrower than the definition of the economist, because in this book we restrict the meaning of the word "production" to the actual creation of marketable products. In an economic discussion "production" means both

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[2] For further information about productivity read Appendix A.

[3] From the United States Bureau of Labor Statistics, August 28, 1962.

TABLE 1-2

INDEXES OF OUTPUT PER MAN-HOUR AND RELATED DATA, 1947–1961
(MAN-HOUR ESTIMATES BASED PRIMARILY ON ESTABLISHMENT DATA; 1957–1959=100)

Item	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961*
Output per man-hour:															
Total private	71.0	73.7	75.7	81.0	83.1	84.9	88.2	89.8	93.8	94.0	97.3	99.6	103.2	105.3	108.9
Agriculture	51.1	60.7	57.9	65.8	64.8	70.5	78.5	84.0	86.9	88.6	94.4	103.0	102.6	108.4	116.4
Nonagricultural industries	76.4	78.0	80.8	85.1	86.5	87.6	90.0	91.4	95.4	95.0	97.6	99.4	103.1	104.7	107.9
Manufacturing	74.8	76.9	78.6	83.8	85.2	86.4	90.6	89.8	96.0	97.1	97.2	98.9	103.7	106.1	110.7
Nonmanufacturing industries	76.8	78.2	82.1	85.6	86.8	87.9	89.0	92.0	94.6	93.5	97.6	99.7	102.6	104.2	106.7
Hours paid per unit of output:															
Total private	140.8	135.6	132.1	123.4	120.4	117.8	113.3	111.4	106.6	106.4	102.7	100.4	96.9	95.0	91.8
Agriculture	195.6	164.9	172.6	151.9	154.3	141.9	127.4	119.1	115.1	112.8	106.0	97.1	97.5	92.2	85.9
Nonagricultural industries	130.9	128.3	123.8	117.5	115.5	114.1	111.1	109.5	104.9	105.3	102.4	100.6	97.0	95.5	92.7
Manufacturing	133.6	130.0	127.2	119.3	117.4	115.7	110.4	111.4	104.1	103.0	102.9	101.1	96.5	94.2	90.3
Nonmanufacturing	130.2	127.9	121.8	116.8	115.2	113.8	112.3	108.7	105.8	106.9	102.4	100.3	97.5	96.0	93.7
Output:†															
Total private	68.4	71.3	70.8	77.3	82.0	84.5	88.6	87.2	95.0	97.1	99.0	97.0	104.0	107.1	108.9
Agriculture	81.2	92.8	88.0	92.8	87.0	90.4	93.7	97.6	102.9	100.5	99.0	100.5	100.0	104.3	105.3
Nonagricultural industries	67.7	70.0	69.8	76.4	81.7	84.1	88.3	86.6	94.6	96.9	99.0	96.8	104.3	107.2	109.1
Manufacturing	71.1	72.6	67.6	78.3	85.7	88.4	97.3	88.1	99.5	102.1	100.7	94.2	105.0	107.1	108.6
Nonmanufacturing	65.9	68.7	71.0	75.5	79.6	81.9	83.7	85.8	92.0	94.1	98.0	98.1	103.8	107.3	109.3
Employment:															
Total private	90.8	91.9	90.0	91.8	95.1	96.1	97.5	95.2	98.9	101.4	101.3	97.9	100.8	102.1	101.0
Agriculture	142.3	137.9	139.4	131.2	123.7	119.4	109.9	108.8	112.6	110.1	104.3	97.9	97.8	95.9	91.6
Nonagricultural industries	85.2	87.0	84.7	87.5	92.0	93.6	96.2	93.7	97.4	100.5	101.0	97.9	101.1	102.7	102.0
Manufacturing	93.8	94.0	87.2	92.0	99.0	100.4	105.8	98.4	101.8	103.9	103.5	96.2	100.3	101.1	98.1
Nonmanufacturing	81.4	83.9	83.6	85.5	89.0	90.6	91.9	91.6	95.5	99.0	99.9	98.7	101.4	103.5	103.7
Man-Hours:															
Total private	96.3	96.7	93.5	95.4	98.7	99.5	100.4	97.1	101.3	103.3	101.7	97.4	100.8	101.7	100.0
Agriculture	158.8	153.0	151.9	141.0	134.2	128.3	119.4	116.2	118.4	113.4	104.9	97.6	97.5	96.2	90.5
Nonagricultural industries	88.6	89.8	86.4	89.8	94.4	96.0	98.1	94.8	99.2	102.0	101.4	97.4	101.2	102.4	101.1
Manufacturing	95.0	94.4	86.0	93.4	100.6	102.3	107.4	98.1	103.6	105.2	103.6	95.2	101.3	100.9	98.1
Nonmanufacturing	85.8	87.9	86.5	88.2	91.7	93.2	94.0	93.3	97.3	100.6	100.4	98.4	101.2	103.0	102.4

making goods and rendering services that add value to a product even though no physical change has taken place. In the economic sense, warehousing, for instance, might add value to the product. In the meaning we shall use here, however, warehousing is not considered production. Production to us will mean that something is done to the material to enhance its value. The change must be either physical or chemical and be achieved through the application of the factors of production (land, labor, and capital). We shall consider repair services as production because actual physical change takes place; similarly, we shall consider as production a certain amount of work which merely adds to the value of an already produced item.

THE REASON FOR PRODUCTION

Generally speaking, production takes place to satisfy human needs manifested in demand. In a much narrower sense, production takes place because nature failed to provide us with all the goods we want. Had nature furnished us with everything in the desired shape, form, and composition, there would be no need for production. If, however, we insist on having and enjoying the use of goods not yet in existence, these items must be created through the process of production.

THE FEASIBILITY OF PRODUCTION

Even though nature did not provide us with every conceivable product, it gave us productive skill and an abundance of natural resources. In other words, nature provided us with labor and land. These two factors enable us to produce what we need or want. Under the assumption that knowledge of how these resources can be combined is available, land and labor can result in production.

The aim of production is a product. Practically everything we see and touch in our everyday life has been produced. Even the water we drink has been purified, that is, produced. If we discount air, trees, and certain other natural items, there remain only a few things which do not have to be produced. Everything we wear, the buildings in which we live, the books we read, the lamp we use for reading, and the bed in which we sleep are produced.

THE FACTORS OF PRODUCTION

Although modern production requires other factors in addition to land and labor, these two are sufficient to produce certain products. A third factor, capital, is a derivative production factor. Modern production is impossible without its employment. While capital results from production, it is reason-

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* Preliminary.

† Output refers to gross national product in 1954 dollars.

NOTE: For information on sources and methodology, see Bureau of Labor Statistics Bulletin 1249 (1959), *Trends in Output per Man-Hour in the Private Economy, 1909-1958.*

SOURCE: United States Department of Labor, Bureau of Labor Statistics.

able to assume that the first capital used by the caveman was not produced but found in its natural form. Ordinarily, however, capital must be produced.

What is capital? Capital is any object used as a tool to facilitate the work of man. It refers not to money, but to the various tools used in modern production. From the simple hammer to the complex automatic transfer machine, everything is capital when used in the production process.

If land and labor are properly combined, it is in certain instances possible to produce without capital; we could therefore say that capital is not absolutely necessary but that labor and land are. Availability of both land and capital, however, would not be sufficient for production. It might be argued that in automation the human element has been eliminated. On careful observation, however, this last statement seems to be only a half-truth. Production without labor is impossible in the absolute sense. Discounting the possibility of automation in the production process, labor is the active production element. For this reason, it is probably true that labor is the most important of all three of the factors of production. Behind every machine and action, there is usually—though not necessarily—a human being. Indeed, without human planning and physical skill, production is inconceivable.

In light of this, it would be shortsighted to attempt to refute the paramount importance of labor even at a time when mechanization and automation are gaining steadily in importance. Since machinery, including automatic equipment, is man-made, man was needed to build production skill into the machine. Thus, regardless of how we look at things, labor as a factor of production is here to stay.[4]

Labor, or Human Resources. The term "labor" refers to both physical and mental skills. Skill is either a natural or an acquired human quality. Skills can be acquired through work experience, trial and error, or outright training of some sort (aping others, apprenticeship, purposeful observation, or classroom teaching).

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[4] According to Walter Bagehot, "Labour . . . the muscular and mental force of man . . . is the main element in almost all kinds of production, and the principal one in many. But we must be careful not to imagine that this labour which the capitalist purchases is one thing. It is hardly even one *kind* of thing. The labour of a ploughman is distinct from that of a clerk; that of a clerk from that of an engine-driver; that of an engine-driver from that of a cabinet-maker; and so on without end. The difference between these various kinds of labour is in a great degree the consequence of acquired habit. Each man is trained in his department, and in it, therefore, he acquires a skill. These various kinds of training go down to very low degrees . . . to the "navvy" who just knows how to dig out plain earth . . . and runs up to the most accomplished artisan . . . the maker of astronomical instruments (say) who can turn out work of the finest and most minute accuracy, and to a great extent know how he does it, and how that accuracy is acquired. There is a common coarse sort of human nature which can be taken a certain way in any pursuit, but which will not go very far; and over and above that, there is a finer element which can only be taken in one direction, or some few directions for which it has an affinity, and which is often accompanied by an incompetence to go even the first step in many others. Out of these natures specifically inclined to it, each trade gets its best labourers." Walter Bagehot, *Cost of Production* (New York: Pitman Publishing Corp., 1930).

Labor can be applied to cultivating the soil, extracting mineral resources, picking apples, making shoes, and to preparing a household meal. Since almost everything is produced, labor is a part of practically every product. This is true to a lesser degree in automatic production, but even there a limited amount of labor is needed to keep operations moving.

Labor as a factor of production is almost invariably used and applied to natural resources, regardless of the state in which they are found. Labor is most likely used to operate some sort of a tool (capital) and perform some productive step to shape and form the raw material (land).

Land, or Raw Materials. Land refers to such natural resources as mineral deposits, forests, and chemical components found in earth, sky, or water. Land, in addition to any animate or inanimate object of nature's creation, might even refer to energy derived through a production process from rivers, waterfalls, or the atom.

Although "land" implies natural resources, the resources do not have to be in their original form. Most raw materials used by a particular factory are the products of other manufacturers, and only improvement or further work need be performed on them. Since every product upon which additional work must be performed might still be called "material," land becomes a production factor only when its usefulness and applicability is discovered. Bauxite, for example, was a useless rock until the development of electrometallurgy made it a practical source of aluminum.

Since land is essential to production, while capital is not, land should be looked upon as the primary or basic factor of production. Since land is as old as the world itself and capital is a derivative factor, production cannot be older than labor.

Capital, or Machinery. Historically speaking, man produced predominantly consumer goods. But at some time or other he might have found a sharp triangular rock formation (land). It is conceivable that through the application of his labor, he combined the rock with the branch of a tree (land). In other words, he produced a capital good (an axe).

Both fruits gathered for immediate consumption and the axe made for future use were products. Yet it is significant that fruits were consumed, but the axe was to be used in the production process to create other goods. The axe was a producer's good. It follows that man had created the third factor of production.

Capital is a product of and, at the same time, a factor in production. Its primary function is to be used as a tool in the production of other goods.

Most production processes today apply tools of some sort. While it is conceivable to undertake production without the use of capital, it would, for example, be foolish to catch fish with bare hands when a net is available. Nevertheless, many items are produced merely through the application of labor and land, without recourse to tools. Picking berries, for instance, seldom requires the use of tools, although the basket into which berries are placed is nothing else but capital.

THE ROLE OF CAPITAL

Capital and capital formation play an important role in the economy. Although this discussion is greatly abbreviated, the significance of capital and capital formation should not be underestimated. Capital and capital formation are important considerations in the decision-making process because of their direct influence on productivity and profitability in general. The fact is that the more and the better the equipment used in the production process, the faster, easier, better, and cheaper industrial production becomes.

Apparently, those nations which have amassed a large amount of capital equipment enjoy a high standard of living. The extensive use of the capital means of production is one of the several important determinants of the wealth of industrial nations.

While production in the early days of economic development referred primarily to turning out consumption goods, modern production creates both consumption and production goods. The fact that money is used in the exchange process and that the profit made on the transaction remains in money form and can be used to acquire capital goods has led to the misconception that money itself is capital. It must be understood that capital is nothing but *vorgetane Arbeit,* that is "stored up labor," but not money.[5] The fact that money received for labor is not fully spent but is instead accumulated and converted into capital equipment through the process of saving does not change the fact that the basis for capital formation is production.

CAPITAL AND PRODUCTIVITY

The more productive the labor, the more is produced per unit of time. To clarify this point, let us think of the early Indian. The hunter, let us assume, dropped rocks on buffalos as they passed through a narrow canyon. Let us say that this method netted him, on the average, six buffalos a year. When he decided to spend part of his time on the production of a bow and arrows, he was unable to hunt and therefore ate less; he had shifted his labor to the production of producer's as opposed to consumer's goods. Now we have assumed that on the average he killed a buffalo every two months by the falling-rock method. By spending, say, four months on the making of bows and arrows, he and his family had to live on four instead of six buffalos per year. The value of a bow and arrows could be expressed, therefore, as being equal to two buffalos. Our Indian had converted his labor into "capital" instead of into good living.

[5] Adolf Weber, the foremost German economist, defined "capital" by this term.

Let us see the significance of capital goods. The Indian then had a bow and arrows and no longer had to wait at the narrow canyon to kill the buffalo. The result was a significant rise in his kill of buffalos and in his standard of living. The use of capital enabled the Indian to produce more consumer's goods with less labor.

This brief explanation indicates that capital is the most important of all products from the point of view of productivity and efficiency.

SPECIALIZATION AND PRODUCTIVITY

Greater productivity can also be achieved through specialization of skills. While capital is important in the technical sense, specialization can cause further increases in the productivity of labor through repetition and the restriction of hand movements. Even though specialization can go on until work is reduced to a limited set of motions instead of encompassing a whole series of tasks, it has definite boundaries. In contrast, the use of equipment has practically no boundaries; rather, it opens new avenues in the more effective use of labor and the application of the specialization principle.

OWNERSHIP, CAPITAL, AND MANAGEMENT

From the preceding discussion there can be no doubt that the use of capital in the production process was early recognized to enhance man's productive power. The craftsman or the merchant-entrepreneur, however, owned and operated only a limited amount of capital equipment. In many enterprises today the per capita, or per employee, dollar value of equipment may run into the tens of thousands.[6] Those who possess the physical skill ordinarily cannot, in the old-fashioned way, own the capital with which they work. Hence, there is a distinct separation between the laboring group and those who own and operate industrial plants.

In the present corporate form of ownership, the stockholders, or capitalists, own the capital means of production and the workers merely offer their productive services to the owners of the capital. This does not, however, preclude the possibility that a worker who saves a certain part of his income cannot also become the part owner of the equipment with which he works.

In view of the peculiar characteristics of money as a store of values and as a medium of exchange, one refers to someone with money, whether saved or inherited, as a capitalist. What is really meant is that the money can be readily converted to capital means of production. Possession of money does not automatically mean that the owner is in fact a capitalist. If the money saved, inherited, or otherwise acquired is kept hidden in the attic, it does not, by any definition, represent capital. Theoretically, it will become capital upon being invested into capital goods used in productive endeavors.

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[6] Capital investment per man may run anywhere from $10,000 to as much as $60,000, averaging about $24,000.

This investing does not have to take a direct form. As a matter of fact, most investment takes place in a roundabout way. In practice, money will find its way into production through various channels. Banks accept savings and time deposits and invest the funds, in which case the saver or depositor participates indirectly in production. The capital was acquired with his money by the bank as a means of safeguarding his savings. Furthermore, savers might invest directly in the capital means of production through stock ownership or by venturing into business as a partner or sole proprietor. Owning and operating very likely also mean managing the business into which capital was invested. That is, those who own and operate the factors of production invested in a business venture tend to be managers as well as owners. Occasionally, they are also the workers.

Being a capitalist in any one of the other senses does not, however, necessarily require active participation in the management of the business and indirectly that of capital. The capitalists may choose to hire professionally trained people who are willing and able to manage the business. In the modern corporate form of production, this is exactly what happens; the shareholder of the corporation's capital stock has little to do with actual management. Actually, average investors are not really interested in managing the business into which they have invested their capital; they merely want a share of the profit their capital produces. But although they are not primarily interested in management, the shareholders of participating common stock are entitled to a voice in management. They can vote on corporate matters in proportion to their capital share. When, however, they vote for a board of directors, they officially turn over management to that board. Thereafter the board is responsible for the affairs of the corporation. In turn, the board generally hires professionally trained men to administer the various functional aspects of corporate affairs.

Accordingly, in modern corporate business, management and ownership of capital are most likely separated from one another. The investor, or capitalist, owns the business at least in part, and corporate management runs it, using the funds supplied by the stockholders to acquire all the factors of production needed for certain productive endeavors. Evidently it is up to corporate management to organize, combine, and utilize these production factors with the utmost care in order to make a profit for the owners.

In the corporate form of enterprise, profitability is not only a desirable end but, to some extent, an end in itself. Unless the corporation is profitable, the investor withdraws his money and puts it into something else which is more profitable. Withdrawing his investment may not abolish the capital, because someone else may acquire it at the market price, but investors tend to shy away from the unprofitable corporation. The result is that when new capital is needed by an unprofitable corporation for expansion, improvement, and new ventures, it is unobtainable on the money market. Therefore, management of corporate enterprises is more or less dedicated to profit making in the production of goods or services. In a sense, management's duty is primarily to produce profits and only secondarily to make goods through which the profit is being made. But, of course, the two aims are largely interdependent.

The ever-present need to modernize and replace obsolete equipment makes corporate profit making extremely important. Any enterprise which is not able to scrap obsolete equipment will be left behind by competitors who, because of their profitability, are able to do so. This can be a vicious circle. Unless one modernizes plant facilities, profit making is reduced by falling efficiency; yet it is profit making that enables the management to acquire the capital necessary for plant improvement. It is therefore not surprising that the corporate management is so preoccupied with profit making.

The production end of business offers the greatest opportunity to make high profits. Professional managers can, by proper management, so arrange the factors of production that with the least input the most output is achieved. Basically, this is the efficiency concept.

MANAGEMENT FOR PROFIT

Since production is only a means to an end, profit is made as a direct result of carefully developed production plans. Effective planning and execution of production activities will result in low-cost operations. The lower the cost of production, the greater the possibility of profit. The need for effective production management is reemphasized by this profit motive.

From what has been said above it can be inferred that, regardless of the excellence of planning, production cannot be sufficiently effective to realize the desired profit without dynamic leadership. Leadership sees to it that the efforts of individuals or groups of individuals are properly directed and unified toward production goals.

In pursuing the profit motive, leadership must permeate the organization. Efficiency can temporarily be achieved by force, but only true leadership can guarantee the unflagging realization of production objectives. Apparently, true leaders do not merely impose their will upon others; instead, the others tend to follow their leaders voluntarily. Hence, the production executive must be skilled enough to direct different individuals and their personal motives toward the common goal. Also, the executive must not only influence the group but be influenced by it. This reciprocal relation is the main characteristic of effective leadership.

At this point it is essential to stop for a moment to digest the reasons why leadership is so important to the effective management of production activities. It should be recalled that management does not concern itself directly with all the factors of production. Since labor possesses skill in the use of the productive factors, management's task is to direct labor in the use of those resources.

Management must therefore develop ways and means of controlling the activities of people. This can be done by planning everything in advance and by seeing to it that action conforms to plans. Leadership becomes important because management manipulates the use of productive resources indirectly through organization, direction, and control of the labor force engaged in production.

MANAGEMENT VERSUS ENTREPRENEURSHIP

It has already been mentioned that entrepreneurs are capitalists who own and use the services of all three factors of production—land, labor, and capital. At the outset, the entrepreneur is both manager and labor. At this stage, however, it is not customary to speak of production management, though management is definitely applied. Management becomes predominant when the entrepreneur restricts his activities to seeing to it that the participating factors of production are properly combined. When the entrepreneur is actively planning, organizing, directing, and controlling the productive actions of others, we speak of production management. Hence, management is characterized by getting things done by other people.

DETERMINANTS OF SUCCESS

Good management—the wise utilization of the factors of production—tends to be assumed a guarantee of effective production. Capable management is indeed crucial to effective production, but the other ingredients must also be excellent or the results will be in doubt. Just as it is the team and not the coach that wins the game, so no manager can create effective production unless the factors of land, labor, and capital are of a sufficiently high quality to permit good results. Hence, managerial performance and success is directly proportional to the quality, quantity, and nature of the available productive resources; results cannot meet expectations, no matter how great the management know-how, unless resources are freely available.

SUMMARY

History of Production

Production, in its simplest form, began with the caveman when he climbed the tree to secure food. Here he was using only labor to secure a product from land to satisfy his basic needs.

The first advance came when he discovered that by making the edge of a stone sharp and attaching a stick to it, he could produce an axe, which in turn could be used to produce other goods. Thus capital, a new factor of production, was created.

Small-scale production was superseded by large-scale production of tombs, pyramids, and other monuments which emperors of the past made for themselves. They were the results of careful planning and were doubtless created through production processes in which specialization and management principles were employed.

Although the productive activities of cavemen and of ancient emperors are not to be underestimated, we have come a long way from them. The need for labor is rapidly diminishing as the manager uses capital equipment and land (raw materials) to produce goods through an almost laborless process called automation. This is exactly opposite to large-scale production in its earlier form. Originally it was not capital equipment which prevailed in mass production, but human labor. However, if we consider that "capital is nothing but an extension of human muscle power," our most modern production differs only in form, not in basic concept. Labor must be harnessed to produce durable goods, say, automatic machines, but after these goods have been produced, labor is only indirectly necessary to automatic production. Labor is needed to maintain equipment; and thus automation has definite limits.

Definition of Production

In this context production is either the creation of goods previously nonexistent or the improvement of those goods. Production, in general, exists to meet human needs. Production takes place because nature gave us resources which are seldom in the form of directly useful products. To meet human needs, resources must be converted into products through a process which we call production.

Factors of Production

To the production of goods three factors are necessary: land, labor, and capital. An additional very important factor is management. This factor of production separates itself from that of labor.

The concept of land includes all natural resources which are contained in finished products. It includes raw materials and other resources which can be extracted from beneath or above the surface of the earth, such as coal, oil, lumber, and salt. It includes those raw materials which are used up during the productive process. Chemicals which exist in the atmosphere or ocean are also a part of this concept. Energy in the form of coal, oil, and rivers can be considered as land; electricity, however, is a product.

The resources available to us become factors of production when their usefulness is discovered and commercial use is made of them.

The concept of capital includes all produced resources that are utilized in the production of other goods. Tools, equipment, and buildings are included in this classification.

The concept of labor refers to the physical effort and skill used in production.

The Meaning of Management

Though both are human skills, the concept of management is distinguished from the concept of labor. Management is more or less a mental skill and is applied to the planning and direction of work activities performed by others. Its function is to bring about an effective utilization of the factors of production.

Although it is commonly assumed that good management alone is a guarantee of good performance, there is little truth in this statement unless we assume that the available factors of production are qualitatively, quantitatively, and proportionately adequate. In other words, in order to bring about excellence of production, it is essential that management be provided with sufficient raw materials, equipment, and skilled, semiskilled, and unskilled labor.

When management is carried out on a part-time basis and the manager owns and operates his business, we speak of entrepreneurship. When the manager stops manual work and devotes his time exclusively to planning, organizing, directing, and controlling the work of subordinates, the transition from entrepreneurship to management has been fully completed. A professional manager in a corporation is not an entrepreneur just because he holds a few shares of stock. Those who divorce themselves from physical work and plan and direct the efforts of others are merely managers. The entrepreneur owns and operates his business.

INSTRUCTIONS ON THE USE OF PROJECTS AND CASES

As indicated by the preface, this book is designed to teach simultaneously principles and their application to actual industrial situations. In turn, application can be practiced either through the project method or the case method. Some teachers consider that learning through the case or project method is better than through the more orthodox lecture method; in the author's opinion, however, it is unthinkable to teach production management solely through the case method, because the various problems are not necessarily soluble by plain common sense. The solution usually requires profound understanding of principles and a recognition of problem areas, as well as possession of the tools and techniques of management. Therefore, this book makes use of case studies primarily to illustrate the applicability of principles under different production and economic conditions. The purpose of projects and cases at the end of each chapter is to make students use their reasoning power in the area of production management. Appropriate use of theory and a skillful manipulation of factual material might give students a taste of industrial life even without being out of the classroom. Despite the value of practical application, no student could solve all the problems which might occur in industry without having acquired some of the tools and techniques used in the process of analysis.

The cases provide repeated and developing experiences in the process of thinking. Each case contains problems the solution of which requires the same kind of mental acrobatics from the student as real problems occurring in industry require of those in charge of production activities. The case will usually present a series of problems of varying degrees of difficulty. Occasionally the case will define the problems to be solved specifically; at other times it might be difficult to see them or their solution without some degree of management knowledge. It will be up to the student to utilize the various managerial tools such as charts, records, and forms to solve the problems at hand. Problems inherent in case studies might require students to suggest alternative solutions. Finally, students must learn to extend their solution to a particular problem into a form of knowledge which will enable solution of other problems of similar nature.

Each of the cases in this text is a collection of typical industrial problems and situations. They are replicas of actual situations occurring in production enterprises. With very few exceptions the cases or the projects contain information relevant to the industry and its competitive conditions. They usually provide historical background pertaining to the company and, especially, facts which influence, hamper, or contribute to the problem which detrimentally affects production. The various cases contained herein report facts or, in some instances, merely present opinions of employees and executives. However, opinions—which must always be analyzed for their validity and reliability—do not imply practical solution possibilities. It is the function of the student to test the validity of opinions expressed. Cases are frequently so constructed that the problem lies in misunderstanding and misinterpreting the opinions expressed. If the student who reads the case, no matter how carefully, is misled by irrelevant information or opinions, his solution might resolve a nonexisting problem and leave the true problem untouched. It must be emphasized, however, that it is by no means intended here to trick the student, but merely to give him a chance to recognize fact from fiction.

Development of a Case Problem

The case might result from statements collected by a consultant. When an enterprise calls in a consultant, the chances are nine in ten that the enterprise is sick or, at least, showing some signs of illness. Those who are part of an organization usually cannot see the real problem or the factors causing it. The company feels the consequences of poor management but fails to pinpoint what is wrong. Whereas the members of an industrial organization cannot recognize the problems at hand, a consultant comes from the outside with open eyes and mind. Frequently, he sees the problem or problems merely because he has a profound knowledge.

A consultant asks questions of everyone who might give information necessary to discover the cause or causes of the illness. Foremen, staff specialists, accountants, and executives are questioned. Production records and output figures are consulted. Observations are made and every relevant fact is carefully investigated. At the end of his investigation the consultant has a body of facts, opinions, and information which is, in fact, the case study of a company.

The student receives such information. Obviously, it is a difficult task to write up a case, but case studies ease the task of the student. They are evidently the results of investigations already performed and condensed. It is better, of course, to learn through seeing and investigating situations right on the spot, but students are not in a position to develop their own case studies. Thus, this book provides them with actual, not armchair, industrial problems.

Analysis of a Case Problem

The next step after the consultant—in this case, the student—is provided with a compact write-up of the case is to solve the problems inherent in the study. His first task is to find all the symptoms of the bad situation. Of course, to do this it is essential to know what is bad. When the company's books indicate that the company is failing to make a profit or is suffering losses or when customers return many products as being defective, we have evidence that something is wrong. Loss of money, failure to meet delivery schedules, overburdened foreman, and high cost of operations are symptoms of company illness. The case study is usually written up in such a way that the student can find all the symptoms. At times, however, symptoms can be discovered only by a comparison of company methods and actions with accepted management principles. Evidently, the student who does not know these principles may not think that anything is wrong with the company.

Finding the Trouble Spot

The symptoms discovered should be listed in sequence, and it is then essential to find out what caused them. It is possible that one symptom is the cause of another. The following symptoms indicative of company illness are frequently listed in classes:

1. Financial losses on several contracts
2. High labor cost
3. Employees not knowing what is expected of them

Since loss is a symptom, high labor cost might cause a rise in the total costs and make production unprofitable. Thus, at times symptom and cause might be identical:

Symptom	Cause
1. Financial loss in production	a. High labor cost
	b. High reject factor
	c. A large number of unsold products (that is, storage costs)
	d. Tool breakage; employee idleness

Symptom 2 appears to be one of the causes of symptom 1. In the final analysis it is usually possible to narrow down the causes to a few significant ones. The main task, of course, is to eliminate the causes by remedying the situation.

SOLVING A CASE PROBLEM

Problem solving consists of eliminating or remedying the cause. Students may naturally experience difficulty with problem solving because they think that there is a pat solution to any given problem. This is, of course, far from true. If we assume that the problem at hand is caused by the unreliability of an employee, one solution would be to fire him. A better solution might be to train him or transfer him to another job requiring less reliability. Obviously, every problem in industrial situations is an involved one. Circumstantial evidence, without further analysis, can lead to a wrong conclusion. For example, it is possible that the employee in question is not really unreliable; his supervisor may simply have failed to explain his job to him. In the final analysis then, the trouble with the "unreliable" employee might be incompetent supervision.

If there are many solutions, it is difficult but not impossible to determine which of them is most likely to succeed. Since it is impossible to test which is the best of, say, four alternative solutions, the student should pick one and present it, provided his answer is backed by proper reasoning. Actually, management follows the same procedure. A seasoned decision is the one arrived at through a careful analysis of all relevant factors. Even though a solution is accepted and introduced in the hope that it will eliminate the problem at hand, it is conceivable that another solution might have worked out better. This, of course, can never be known, except in some cases dealing with operations research (see Chapter 15) where the answer can be tested through mathematical calculations.

Students of case studies are expected to learn by projecting themselves into factory situations in which they are forced to analyze the factors they consider relevant to the case. They must consider various alternatives and communicate their ideas in class (based on written homework papers) by engaging in discussion during class debates.

CARRYING OUT THE CASE ASSIGNMENT

Students should read the case at least twice. The first reading should be quick; the second more thoughtful. They should ask themselves some of the following questions:

1. Is this company in good shape?
2. What seems to be the overall trouble?
3. Are there apparent violations of good principles?
4. How does this company compare with others?

5. Do all the managers fulfill their functions?
6. What is the function of this man or that form?
7. Does this company have a system?
8. What, if anything, is wrong with the company's system?
9. Are the plans and actions adequate to solve the problems?
10. Do the people involved work as a team?

Many other questions of this nature might be constructed. They help in the appraisal of the situation at hand and lead to discovery of symptoms of company illness. These symptoms, if traced to the ultimate causes, should result in reasonably compact statements and indicate the basic problems confronting the company.

Finally, the course of action, the plan, to remedy the situation or the problem at hand must be worked out. While working out the plan, the limiting factors and even the intangible factors must be taken into consideration. That occasionally guesswork is involved in the solution of a problem is evident. According to statistical decision theory, guesswork in decision making—due to inadequate data at the disposal of the planner—should be not a guess in the ordinary connotation of the word, but a decision which takes into account both probability factors and costs. The case analysis should therefore keep guesswork out of the answer as much as possible. But, of course, we are very often forced to act on the basis of incomplete knowledge.

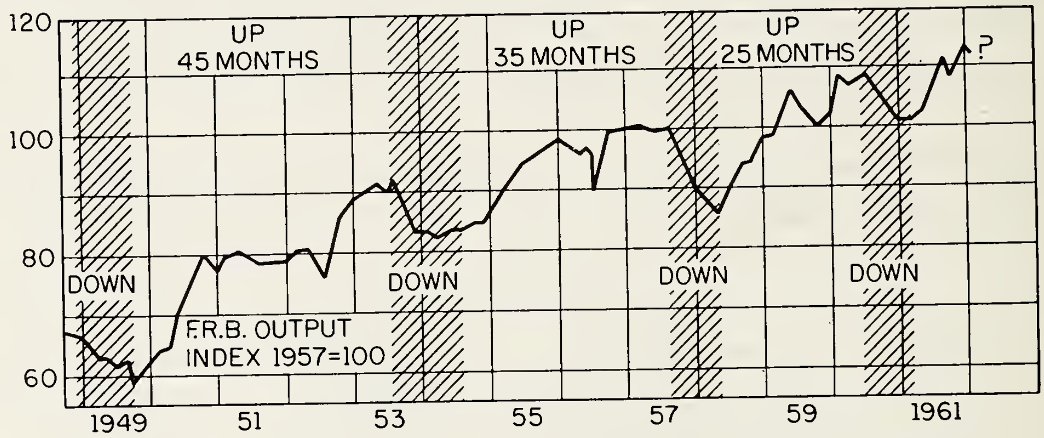

Fig. 1-2. Business cycle ups and downs. (Courtesy of United States Department of Labor.)

In light of the preceding paragraph, students might occasionally feel the need for additional information, and possibly additional information should be available. The fact of the matter is, however, that all factors may not be known at the time a problem arises. More often than not, the case study contains all the information needed for the solution of the problem, but some students, in their attempt to take a shortcut, will not bother to read the case carefully enough to discover the details still needed to make intelligent decisions or at least intelligent conjectures.

How to learn the structure of the subject of production is unknown, but since organizational and functional relations constitute the core of production, it is essential that the student learn how things are related. The various interrelated factors are, in the majority of cases, incorporated in the case studies. The student is assured that the information the cases contain is not tricky or misleading in any way. Every case study in this book is a true industrial situation, and the presentation is as accurate as the observer has seen things. All factors known to the case writer have been presented and made available to the student. Furthermore, most of the cases arose during the ups and downs of the last ten years or so as indicated by Fig. 1-2, to which the student should occasionally make reference.

QUESTIONS

1-1. Define production and try to differentiate between production in general and industrial production in particular.

1-2. What is the function of management in production?

1-3. What is the difference between production of ancient times and production of today?

1-4. What is the contribution of the individual enterprise to the nation's productivity?

1-5. What is the difference, if any, between productivity and efficiency?

1-6. How are productivity and efficiency measured?

1-7. How can management achieve effective production?

1-8. What is the paradox of productivity as far as the individual enterprise versus the economy is concerned?

1-9. Explain the meaning of land, labor, and capital and how they are combined with one another.

1-10. Differentiate between entrepreneur and manager.

1-11. Is it true that the productivity of American industry is attributable to our management skill and know-how? Explain your answer.

1-12. What characterizes modern production?

1-13. Differentiate between management and production management.

1-14. Lawrence A. Appley of the American Management Association said: "Management is personnel administration." Is this statement compatible with the concept of production management?

1-15. What is a product?

PROJECTS

1-1. Look around the room you are sitting in and list the products you see.

1-2. Do you think that any of the same products were used by early man? If so, try to figure out how early man produced the product in question. Finally, decide on the possible differences between ancient and modern production of that product.

1-3. Try to list the differences between production management thousands of years ago and production management of today.

1-4. An enterprise produces 2 million automobile bumpers per year and spent, during the past ten years, the following labor hours for each year's production: 100,000, 100,008, 98,000, 99,000, 79,000, 104,000, 100,000, 89,000, 99,000, and 90,000. During this same period of time the profits of the company on this item were $32,000, $43,000, $33,000, $15,000, $27,000, $29,000, $17,000, $20,000, $24,000, and $21,000, respectively. The labor cost amounted to the same amount of dollars as the total manhours of labor spent on the job ($100,000, $100,008, etc.). For the sake of simplicity let us also assume that overhead cost was 50 per cent of labor cost and that material cost was $5 per bumper.

Determine the improvement or deterioration of efficiency and productivity in this company. Express, in form of a ratio, the improvement or decline in productivity between two successive years. Express in the same way the changes in efficiency between successive years.

1-5. Obtain the yearly financial statement of a company for the past five years. On the basis of various figures determine the efficiency of the company's operations.

CASES

1-1. The Huxley Steel and Bolt Company

Huxley Steel and Bolt Company produces a large number of steel products. In 1946, the company's shaft and cam division was relocated. Simultaneously, production facilities were rearranged to adapt plant operations to the postwar requirements. With the exception of moving and related expenses, this was accomplished without any substantial financial investment.

To understand current difficulties, it is essential to know that the shaft and cam division was organized back in 1942 as a direct result of several military orders received by the company. The products ordered by the government required certain moving parts which, though obtainable at the time, were not to be had as quickly as company production schedules and delivery commitments necessitated. Since the execution of the military contract was impossible without the shafts and cams, the company had little choice but to establish a division to manufacture them. Accordingly, the necessary facilities were acquired. To make use of the excess capacity in the shaft and cam facility, the Huxley Steel and Bolt Company accepted orders from other companies. Ultimately, the shaft and cam division added to the company's profit-making ability. Huxley Steel and Bolt Company eventually became one of the biggest shaft and cam manufacturers in the country. In 1946, equipment and facilities used in the production of shafts and cams were moved to Chicago and were placed in the northeast section of the company's plant.

The 1942 venture, even though considered a sideline activity, had turned out to be very profitable. Shafts and cams were originally produced to escape the financial consequences of the government's penalty clause on late shipments rather than to extend the company's line of products, but it soon became apparent that the division constituted an essential element in Huxley Steel and Bolt Company's financial operations. Yet because it was an auxiliary unit, company policy permitted only a minimum expenditure for maintenance. At the time of the conversion from war- to peacetime production, economy was the watchword and every extra dollar earned was invested only in the kind of facilities which were considered useful in the company's peacetime production program. Huxley Steel and Bolt Company, like all other major businesses, concentrated its efforts on expansion and modernization of its facilities, but in line with the policy established in 1942, the shaft and cam division, because of its auxiliary nature, was neither modernized nor maintained. When Mr. King, the plant superintendent, asked for funds to make some necessary improvements, Mr. Huxley usually replied, "John, would you buy new furniture a day before your funeral?"

Thus, despite Mr. King's efforts, nothing constructive was done about the shaft and cam division. Although it was no longer just a sideline business, but a major money-maker, any time Mr. King voiced his feelings, most executives assumed that he was fighting not for the interest of the company but for his own job.

Early in 1961 it became apparent to Mr. King that unless something more than superficial repair was done about his division, its efficiency would be seriously affected. This would simultaneously cause an appreciable decline in profitability of the Huxley Steel and Bolt Company. When the decline actually occurred in 1961, the members of the board of directors were undecided whether to abandon the division or rebuild it as the most desirable course of action.

In the subsequently described board of directors meeting, the issue of retaining or scrapping shaft and cam's production facilities was hotly debated. Mr. Huxley stated, "In the same solemnity with which we regard our responsibilities, we are also cognizant of the vicissitudes of our business. This does not mean, however, that we should not correct our problems if they are in our own hands. The rather abrupt downward movement of business activity during 1959–1960, which continued in 1961, prevented our dollar revenues from rising and caused profits to decline faster and further than might have been expected. After careful investigation, everything tends to point toward the fact that this deplorable situation can be attributed to the decline in productivity of our shaft and cam division." He stated further that Mr. King, the division's superintendent, was after larger appropriations, but, he added quickly, "We stand firm in believing that, regardless of how important a division is, when its usefulness is declining to the point of losing money, we will always refuse to retain a department which can survive only if supported by the earnings of other divisions of the company. As a result of the self-examination which we conducted last year, we are doubly aware of our duties, responsibilities, and obligations. We will endeavor, therefore, to eliminate any activity which, if continued, could put us in an unfortunate predicament. Our records tend to indicate that the reason for the recent lack of profitability lies mainly, if not entirely, in the shaft and cam division. I suggest, therefore, that we consider the possibility of abandoning the manufacture of shafts and cams even though it was highly profitable during and after the war. The fact is that it has been slipping ever since the Korean War back in 1950 to 1952. It looks to me as if some of our machines, just like human beings, got hot and tired and began to make mistakes. Apparently, shaft and cam production was a good business even during the postwar years, but it has been losing money as of recent date, as our good friend Mr. Bixler [the secretary-treasurer] will tell you in his report."

Mr. Bixler in his report stated: "While our firm had, under the troublesome economic circumstances, a successful year measured in sales volume, our operating revenues failed to follow suit. Furthermore, while our operating revenues rose in face of declining business throughout the country, our profits steadily declined until this fiscal year, when our books show a total loss of $175,000 as shown in Exhibit 2. Our fiscal records indicate that the efficiency of our operations is slipping. This is particularly true so far as the shaft and cam division is concerned. Costs, especially labor costs, rose to such an extent that it has gradually become impractical to operate the shaft and cam division. Unless our purpose is to serve the public regardless of losses, my opinion is that the shaft and cam division has to go. I believe that all of you will agree with me that we are here to make money, not to keep busy for the sake of being busy. As treasurer of this organization I look at the books, and I am truly sorry to report to you that our financial statements explicitly indicate that both productivity and efficiency of the shaft and cam division are below par."

Mr. King, also invited to present his side of the story to the board, took the stand: "Gentlemen: As is prevalent nowadays, we are confronted by rising costs. Since I fully agree that we have to do our best to hold the line on prices, the best way to accomplish this is to improve efficiency and hold down costs. This means that we should, in addition to modernization, worry about customer satisfaction by giving them quality goods at low prices and

EXHIBIT 1

Index of Man-Hours, 1942–61
Shaft and Cam Division
(1944=100)

Based on yearly total man-hours of labor spent on the output:

$$\frac{\text{Output, tons}}{\text{Labor, man-hours}}$$

1961	97
1960	96
1959	82
1958	90
1957	87
1956	89
1955	84
1954	98
1953	90
1952	90
1951	108
1950	110
1949	120
1948	115
1947	120
1946	127
1945	107
1944	100
1943	90
1942	75

EXHIBIT 2

Income Statistics (Million $)
Consolidated Earnings

Year	Net sales	Net bef. taxes	Net inc.
1961	35.08	—	0.17 loss
1960	34.94	2.99	1.35
1959	72.29	10.25	4.87
1958	43.94	3.88	1.85
1957	34.94	2.88	1.55
1956	88.83	9.92	5.46
1955	71.14	8.27	4.88

EXHIBIT 3

Depreciation on Equipment, per cent

1961	0
1960	0
1959	0
1958	0
1957	0
1956	0
1955	0
1954	0
1953	0
1952	0
1951	0
1950	5
1949	10
1948	10
1947	10
1946	10
1945	10
1944	13
1943	15
1942	17

EXHIBIT 4*a*

Labor Cost vs.
Overhead Ratio

1:1

EXHIBIT 4*b*

Composition of
Overhead Charges

30% Adm. exp.
70% Deprec.
100% Overhead

EXHIBIT 4*c*

Cost Estimating
(Std. Cost Data)

Materials cost ________
Labor cost (time card time × wage rate ________
Overhead cost (100% of labor) ________
Total cost
10% profit ________
Bid price, FOB
Total revenue
− Sales expenses ________
Mfg. revenue
− Total cost of prod. ________
Profit

According to a figure in accordance with true cost data, that is, 30% overhead in lieu of 100% as charged by the company, the contribution of Shaft and Cam Division to Huxley's *net income* represents on the average 17% of net income of consolidated earnings. (Data compiled by Office of the Superintendent, Shaft and Cam Division, based on accrued costs as compiled by the cost accounting department of the company, but prorated in accordance with actual cost data as far as capital costs are concerned. Maintenance and materials-handling overhead based on actual payroll records were deducted, since they were not applicable to the Shaft and Cam Division.)

meeting delivery promises and take care of our obligations toward stockholders as well as the general public. To do so, some of our past policies have to undergo drastic changes. I am referring now to policies detrimentally affecting the shaft and cam division."

Mr. King explained that, while in business everything is measured in monetary terms, "You gentlemen should realize that there is a production end of business. While success in production can be measured in profit, we all know that profit can be produced in the shop and nowhere else. To the layman, productivity of labor at the shaft and cam division might have appeared low, but for your information there is nothing wrong with it under the circumstances." He explained that the criticism against his division was unfounded, for the alleged inefficiency in his division could be attributed particularly to two faulty company practices: 1) for years bidding methods which were fully unrealistic were employed; 2) contracts were charged with cost which were never accrued. These practices made his division look inefficient and less productive than other departments. He continued:

"As soon as you hear my facts, you are bound to agree with me that the criticism voiced against the shaft and cam division results from misinterpretation of vital facts.

"For the time being may I merely indicate that prior to being forced by the prevailing economic conditions to produce more and more in broken lots as opposed to economic lot quantities, shaft and cam's efficiency and productivity were rated rather high. If we could somehow raise our sales volume, as well as change the above-mentioned shortcomings, this state of affairs might become possible again. Thus, productivity and efficiency could easily be raised, as can be seen from Exhibit 1."

About the prevailing situation in the shaft and cam division he subsequently listed the following:

"1. Since it was unknown back in 1942 whether in the postwar period demand for shafts and cams could be sustained, it was our policy to make only minor repairs sufficient to maintain operations without putting a dent into the budget of the firm. Although facts indicate the permanency of the shaft and cam business, Mr. Huxley was apparently too conservative to allow adequate maintenance or replacement expenditures for my division. This was despite the fact that my division was one of the main contributors to the company's profitability. As a direct consequence of inadequate maintenance of plant facilities, the shaft and cam division failed to raise productivity to the fullest extent possible even though, with the improved labor skill and experience in the shaft and cam business, it could have been raised.

"Cost and profit figures, as reported by Mr. Bixler, indicate inefficiency in the shaft and cam division, but let us remember that only out-of-pocket expenses can be legitimately counted, for no capital costs occurred in connection with the production facilities. Their value has already been fully depreciated. Hence, as far as equipment is concerned, it costs Huxley Steel and Bolt Company next to nothing to operate the shaft and cam division. Of course, our administrative cost and other related overhead expenses, in addition to the out-of-pocket costs, must be calculated. Yet, 100% depreciation based on company-wide capital values has constantly been calculated. In view of the fact that depreciation value of the shaft and cam's production facilities is equal to zero, it is unrealistic to charge 100% overhead to every dollar's worth of direct labor cost. Precisely because of this kind of cost accounting and bidding practice, it has been doubly difficult to solicit new business. While other firms made realistic bids, we were virtually overcharging our customers. Thus, we precipitated trouble which now manifests itself in low sales volume as far as shafts and cams are concerned. In reality, we could have successfully competed with everybody had we neglected charging depreciation, which in reality we did not have anyway. By charging cost which we did not have, that is, charging for the use of capital, we have priced ourselves out of the market.

"2. Even with equipment so badly in need of repair, I admit my division should not have had difficulty in meeting delivery promises. However, frequent breakdowns of certain machines in 1961 at the wrong moment virtually prevented the orderly flow of production and disrupted operations in general. Despite these difficulties, it should be remembered that, owing to our know-how and experience, efficiency and productivity per man-hour of labor of my division is nearly 50 per cent higher today than it was back in 1942 when the equipment in question was brand new.

"3. This department earns in the neighborhood of 17 per cent of total company profits. Thus, opinions or reports to the contrary cannot be but misrepresentations. When costs are prorated, as they should be prorated, the figures are bound to show that both productivity and efficiency of the shaft and cam division were superior to those of many other departments of the Huxley Steel and Bolt Company.

"I agree that these facts are not apparent from the financial reports you read, but these are indeed the facts and I can prove that they are. Frankly, I would not have presented them to you if I had not sincerely believed that you are interested in facts of this kind. This is not a question of keeping or losing one's job but of airing the situation so that improvement can be effected. I sincerely hope that I have convinced you that the shaft and cam division should not be scrapped. It is no doubt true that certain segments of our company are slipping, but as you can clearly see from my report, it is not the shaft and cam division.

"Without trying to say which department is slipping—because I really don't know—I would like to add a few more facts to throw light on the report presented by Mr. Bixler. According to our cost accounting department, the profit and loss statement indicates that shaft and cam division is $100,000 in the red this year. I believe this was the figure which brought about the contemplated doing away with my job and the division as a whole. According to records which were admittedly prepared for the sole purpose of contradicting the treasurer's report, the company purchased, from 1942 to 1945 the following pieces of equipment: 1) ten different types of special-purpose machines, 2) twenty-nine standard equipment and other auxiliary facilities. As you probably know, the parts we needed to complete a government contract were at the time not easily obtainable on the open market. Thus, we decided to make them ourselves and solicited Internal Revenue support. The tax authorities, based on a certificate of necessity from the government, permitted us to depreciate the equipment in 60 months. Because not all equipment was bought at one time, actually 120 months was needed to write off all these machines. This depreciation plan was instrumental in setting up the shaft and cam division. The equipment would, I believe, be good for at least 25 or 30 years. With proper maintenance and care, life expectancy of the equipment was said to be 50 years. Under these conditions, it was not difficult to convince the company to install facilities to manufacture the items in question.

"Based on a 120-month amortization period, the depreciation rate turned out to be 17% in 1942, 15% in 1943, 13% in 1944, 10% in 1945, 10% in 1946, 10% in 1947, 10% in 1948, 10% in 1949, and 5% in 1950 of the total capital investment. You are bound to notice that we had nothing to depreciate during the last 12 years, yet depreciation was calculated as a matter of course. If depreciation, in form of the normal overhead calculation, had been calculated, the loss of $100,000 could not have been anything but paper loss. Based on our estimates, the overhead calculation contains approximately 70% for depreciation charges and only 30% for other overhead items. Deduct the 70% from the cost figures collected by cost accounting and you will find that my department produced a net profit of considerable magnitude. In this connection I refer you to Exhibits 3 and 4.

"Despite high cost of depreciation, the shaft and cam division operated highly successfully during the years 1942 to 1946, and at a satisfactory rate ever since. Now that we have ended up with a total company loss of $175,000 it is very convenient to look for a scapegoat in the shaft and cam division. That division doesn't qualify. According to my privately kept records, it shows a pure profit of at least $100,000. It should be pointed out, of course, that the alleged loss attributed to my department is fictitious inasmuch as it was caused mainly by a depreciation charge due to an erroneous cost accounting practice.

"Gentlemen, this is the picture, as I see things. If I have said too much and if I have unwittingly or by implication attacked any individual, please understand that I was as impersonal as I could have been under the circumstances. This profit was achieved despite an actual decline in the productivity of labor resulting from the all-too-frequent broken-lot production forced upon us by a sudden decline in the sales volume. The cause of declining productivity and efficiency can, however, also be attributed to the fact that, after so many years, our equipment began to give trouble. We made no replacement, either of worn-out parts or of obsolete equipment. Hence, employees were instructed to run equipment at a safe speed and exercise extreme caution to prevent rejection of workpieces.

"I have to admit that productivity-wise we should have done better. However, considering the above facts, in addition to the added costs resulting from broken-lot production, I believe that labor productivity has improved to some extent in comparison with previous years. This might be attributed, of course, to the general fear of losing one's job. A depressed economy will always influence the willingness of employees to work harder. This improvement was especially true in my department where layoffs were quite heavy from December, 1960, to March, 1961.

"According to our records based on time cards and tabulated output figures, our departmental productivity went up 1.7% in comparison with recent years, even though the declining tendency was by no means halted. Nevertheless, last and this year's productivity was lower than the all-time high of 127%, which occurred in 1946, as compared with the base year, 1944.

"Despite contradictory evidence, I suggest retaining my division, including all the equipment. I would also like to recommend undertaking appropriate study of competitive conditions in the particular field of shaft and cam production. For the time being, I would like to ask for a modest increase in the budget for maintenance work and for replacement of equipment. Furthermore, I suggest that we revamp our cost accounting and bidding procedures to make them more suitable for accurate and rational operations. A 100% overhead based on the value of overall company facilities at a time when no depreciation costs are really involved is obviously unrealistic, and a disregard of its importance might add to further deterioration of our position in the industry as a whole and will hide the real cause of our falling profitability. Gentlemen, thank you for your time and patience in hearing me out."

Questions. The student can resolve the problems raised during analysis of the case by defining the following: cost, productivity, efficiency, productivity per man-hour of labor, production, and profitability. Of course, this is not an easy task because of the different interpretations of these terms. The problem of the Huxley Steel and Bolt Company appears to be a complicated one, and decision making hinges upon the proper analysis of the facts listed in the case. However, the student can resolve the problems easily if he understands what the various terms really mean. The questions listed below are sample ones. The student and the instructor can ask as many questions as are deemed necessary to resolve the problem or problems at hand. A systematic answering of the following questions might help the student resolve the problems and permit appropriate recommendations in light of past happenings.

1. Considering the pros and cons, determine a) whether the company was efficient, b) whether it was poorly managed, c) whether its labor productivity was high, d) whether the shaft and cam division was efficient.

2. List the symptoms indicating that production is slipping. If you disagree, list those symptoms indicating that it is not deteriorating by taking the definition of efficiency or productivity of labor into consideration.

3. List the symptoms and also those factors which apparently cause the problem or problems at hand.

4. Suggest ways and means to eliminate the causes which you have listed. While you do so, you are permitted to agree or disagree with company officials.

5. On the basis of the arguments presented, do you think that the Huxley Steel and Bolt Company should abandon the production of shafts and cams?

6. Determine production and economic conditions which prevailed during the period in question and the marketing problem at the time the question of abandoning the shaft and cam division arose. On the basis of your findings, act in the capacity of a consultant and advise the management.
   a. What would be the advantage, if any, if the company abandoned the shaft and cam division?
   b. How would abandonment affect the company's relative position in the industry?
   c. Contrast the advantages and the disadvantages.
   d. Make your recommendation or recommendations.

7. Criticize the validity and reliability of the statements made by the various executives. Base your criticism on the principles which were presented in Chapter 1: the question of land (material cost), labor (wages), and capital (depreciation) as factors of production; the method of assigning dollar values to these factors; and cost development in general.

8. What, if anything, is wrong with the management of Huxley Steel and Bolt Company?

chapter 2

The Nature of Modern Production

INDUSTRIAL PRODUCTION

Modern industrial production is wholely different from handicraft. Unless assisted by members of their families, journeymen, or apprentices, craftsmen worked alone. In our connotation, division of labor did not exist. In contrast to this, modern production is based on the division of labor. A complex job is divided into simple, repetitive tasks and every employee is assigned only a small portion of the total work load. Since the job is rather routine, men become experts in performing a highly specialized job. Whereas a shoemaker of years ago did everything from cutting the leather, sole, and lining to assembling the workpieces, sewing all the necessary seams and even shining the finished shoes, workers in a shoe factory often do nothing more than a simple job such as lacing shoes or stamping soles. This structural change becomes quite apparent to a visitor who walks through a modern shoe plant. The existence of occupations such as lacers, cutters, buffers, and stitchers indicates that production has become increasingly the result of teamwork of men and women performing highly specialized work under the watchful supervision of management.

THE FACTORY

The place of production is the factory where work is performed by skilled, semiskilled or unskilled workmen. Factories are places, usually buildings, where the necessary equipment is brought together and where workers gather for the purpose of producing. Factory work, like any other production work, consists of converting natural resources into raw materials or the latter into semifinished or finished goods.

THE INDUSTRY

A common error in industrial parlance is to refer to a particular plant as an industry. The term "industry" should not be used; the proper word is "enterprise." A factory or an industrial plant is only a part of an industry.

"Industry" is the collective name for a given type of industrial activity; examples are the plastics, steel, electronics, chemical, and pharmaceutical industries. Companies like United States Steel, Westinghouse Electric, E. I. duPont de Nemours, and Eli Lilly are only parts of the steel, electronics, chemical, and pharmaceutical industries.

The industry is the composite of a large number of small as well as large enterprises engaged in a certain type of production. Size does not make any difference. Large companies may operate several plants or divisions, and even though they may be located in different parts of the country, or even abroad, they still belong to one and the same company and constitute a part of the industry as a whole. The judicial reference to an enterprise does not preclude independent factory operations in the various plants or divisions. Although Buick, Pontiac, and Chevrolet are divisions of General Motors Corporation and operate independently, all component divisions are General Motors enterprises.

It is conceivable that a large company may be a part of several industries. The Firestone Tire and Rubber Company, for instance, operates not only in the rubber industry—even though its major income is still derived from the production of rubber tires—but is also engaged in the production of approximately 12,000 other product lines in six major industrial fields: rubber, metals, plastics, synthetics, textiles, and chemicals.

Industrial classification can take different forms. Often, reference is made to the mining, electroplating, woodworking, metalworking, manufacturing, and meatpacking industries, where the industry is classified according to the general nature of the production process. A yet broader classification divides the great multiplicity of industrial enterprises into primary industrial groups and the finishing industries. In other instances reference is made to furniture, automobile, appliance, motion picture, and coal industries, where the industry is classified by the resultant product. Yet management as a skill remains the same regardless of the nature of production. It is essential to keep this fact always in mind. The nature and scope of production have little to do with the quality of management.

Transferability of Managerial Skill

Although it is commonly assumed that each product or industrial activity requires a specific type of managerial skill, subsequent explanation will reveal the fallacy of this assumption. A close look at production will indicate that line management deals primarily with people, while staff personnel engaged in production planning, including plant layout and output standards, deal with the physical aspects of production.

It must be apparent that, no matter what the nature of production, the skill required to deal with people cannot be subject to substantial changes, and it must also be apparent that what machine and what operation are involved is of secondary importance as far as the production planner is concerned. He merely deals with a "machine" and what it can do, what quantity it can produce, and when it is available for production.

Though line personnel deal primarily with people, they also deal indirectly with machines. Planning, however, is primarily concerned with the use of physical facilities. The planner's work, if separated from line activity, is apparently complementary to the work of the executor. The executor assigns the men to the various machines, yet the planner is the one who indicates in a predetermined plan when the assignment can best be made or if it can be made at all. The planner usually knows when the machine is available for a given type of work.

From the point of view of operating management, the skill of employees is all important. At higher managerial levels the same thing is true, but of course in a different connotation. The capabilities of subordinate managers must be appraised in the same way that the skill of a machine operator—at the operating level—is considered in the light of the task which must be accomplished. What industrial activity is involved is relatively unimportant. Employees have basic skills, such as operating milling machines, servicing boilers, running plastic or concrete mixers, and operating open-hearth furnaces. Of course, there are different degrees of skill with which these employees can perform each activity. Some employees can make proper use of a paint brush, but one may be able to accomplish a painting job qualitatively better than the others. So it is that the supervisor must always pick the right man and assign the task to the workman who possesses the required skill to the highest possible extent. This is a judgment based on observation of human skills, and the ability to appraise the performance of others is a universally applicable skill.

While at the operating level management implies some degree of know-how and of technical knowledge of the equipment involved, at higher levels this is not necessarily so. The higher the managerial level the lower is the requirement of specific technical skills. Most managers have been trained in the production of certain goods, but in their capacities as managers they usually deal with production activities not directly, but only through other people. Their main task is then the appraisal of the willingness and personal abilities of subordinates to assume responsibility for the outcome of contemplated production assignments. At the operating level, however, the physical skill of workers, along with their human attributes, are appraised. Obviously, the success of production depends largely on the availability of employee skill on the one hand and supervisory ability on the other.

This transferability of managerial skill can be demonstrated by the fact that many individuals whose preparation and experience have ordinarily been confined to one type of industrial activity have successfully changed to the production of something else. Executives can and indeed do move from one firm to another and are able to take over elsewhere with as great or greater success than if they had kept to their original specialties. This by no means implies that a production executive can tackle everything, but it illustrates that the basic managerial skills needed in one type of industry are no different from those needed in another. It is not surprising, therefore, that a production executive who has been accustomed to producing simple items in one company can transfer his skill and know-how to the production of a rather complicated product.

No matter what the product is, production executives delegate authority for the actual operations to lower managerial levels; and the authority ultimately permeates down to the supervisory level. Production foremen in turn assign jobs to workers who appear to be suitable for the jobs in question. Although most jobs involve the use of equipment and raw materials, it cannot be denied that behind these physical production factors are people. The activity of planning the effective use of physical facilities is something quite different from utilizing the human factor in production.

Thus, Lawrence A. Appley's remark "management is personnel administration"[1] applies to production as well as to any other field of industrial endeavor. We always deal with people. People plan the work and people execute the plans. We plan the use of things, but we assign men to use them in the proper time in the proper manner. People with skill and managerial abilities are the cardinal determinants of successful production, and the nature and purpose of production are of subordinate importance. Even though we refer also to 1) extractive, 2) analytical, 3) synthetic, 4) manufacturing (fabricating), and 5) assembly types of production processes, these terms say little about the managerial problems behind them. Even though an enterprise engaged in extracting differs from a manufacturing company and a synthetic production activity differs from an analytical production process, these differences are primarily surface ones. Production in general and industrial activities in particular have a common denominator. Let us discover, then, what makes one industrial activity just like another from the managerial point of view.

Industrial activity has several goals, but one of them towers over the other: production of goods on a profitable basis. Whether the production is of finished goods or of semifinished goods is immaterial. What is to us a finished product is likely to be a raw material where another enterprise is concerned.

The statement that managerial skill is transferable might create the impression that technical knowledge is not necessary to production. This statement is true only to the extent that where technical problems are solved by staff personnel, the supervisory job is often relegated to selecting suitable men and directing and controlling them in the production process. Where such managerial separation does not take place, management, of necessity, implies both technical and managerial skills.

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[1] Lawrence A. Appley is the president of the American Management Association, a prominent professional organization in the United States.

This discussion has shown that however complicated the nature of production, however complicated the equipment involved, and however great the number of raw materials used in the production process, the outcome of production depends on the relationship between man and man. Production is the result of communication among those who assume responsibility for certain phases of production. At the end of the line the supervisor communicates plans to the employees and interprets for them the necessary details. Out of this human relationship results the activity which is referred to as production.

CLASSIFICATION BY METHOD

Although the relationship between many production processes is so intimate that a differentiation between them is almost impossible, an imaginary line of demarcation is warranted. The ties binding industries together may be natural or functional. A lumberyard is often associated with forestry, trimming, saw milling and other activities; coal mining with coking, smelting, steelmaking, and by-product utilization. Thus, an enterprise may be engaged in several different production processes, but the plant must consist of a number of dovetailed, even if independent, processes.

Chronologically, the first production process is the extractive process. To this type of production belong the various branches of the mining industry (ore, diamond, coal, and construction materials), drilling industries (oil and natural gas), forestry, fishery, hunting industries, and so on. The extractive process results in products which are usually considered as basic raw materials. According to another classification, these are the primary industries. Of course, before the felled tree becomes commercially useful, or iron ore becomes a finished steel part in an automobile, or crude oil becomes commercially useful gasoline, it has gone through not only the extractive process but also other types of production processes.

After the extractive process, the product may have to go through, say, a refining process. This can conceivably be an analytical process. Sugar beets, for instance, must be washed and cut into small pieces, and the sugar must be separated from the particles; crude oil must be separated into its constituent chemical compounds (gasoline, kerosene, fuel oil, and lubricating oils) coal must be broken down into gas, coke, tar, ammonia, naphtha, phosphorus, and other chemical components. Within the analytical process, we may find different production techniques such as separation of components through heat (iron from iron ore), distillation (salt from salt water), centrifugal separation (butter from milk—the buttermilk is a by-product), and electro-analytical separation (aluminum from bauxite).

Products resulting from the analytical process may be combined through the synthetic production process. Whether this synthesis of several chemical elements is done under the influence of hydraulic pressure, heat, or electric energy is unimportant. The products thus derived are the synthetics such as synthetic rubber, industrial diamonds, nylon, and plastics of all kinds; glass; alloy steel and other alloy metals; chrome or nickel plating; gold and silver plating. The synthetic production process can create entirely new products hitherto unknown, such as nylon and polyester resins, or add to the value of old products, as costume jewelry made of brass might become expensive looking by being gold-plated.

The steel industry and most other industries employ several different production processes. Iron making is primarily an analytical production process; but the production of alloy steel, for example, stainless steel, requires a synthetic process since an alloy is a combination of several metals. Furthermore, most steel firms are also engaged in the shaping and forming of the metal thus created. The latter is called either "fabrication" or "manufacturing." A forge company always changes the shape and form of metals under pressure and heat; a foundry, in a similar manner but without application of pressure, pours the fluid metal into a mold. When the metal cools, it assumes the shape and form of the mold. This product is the "casting." The machine shops perform further fabrication, such as shaping the casting to proper dimensions, drilling holes, or bending in accordance with design requirements. Thus, a machine shop may turn a casting into an engine block which in turn will house a large number of motor parts. A machine shop can be engaged in fabrication of machine parts in general. But a tailor's shop is also engaged in manufacturing. The material is cut into different shapes and forms such things as sleeves, collars, and pockets. As a rule a part is not useful as far as the ultimate customer is concerned unless it goes through the last production process: assembly.

A manufacturer may produce automobile bumpers, crankshafts and many other automobile parts, but as far as the assembly plant is concerned these are nothing but raw materials necessary to production. The assembly production process puts parts together and thereby creates new products. Many items purchased in the store by the consumer are the result of the assembly process. Most automobile manufacturers are engaged in fabrication as well as in assembly. At times they also engage in some synthetic production. Thus, for instance, while the fenders are assembled, spot-welding joins the parts together; that is, the latter is a synthetic process rather than assembly as used in this sense.

The nature of the activity is of greater importance than the product to be produced. Hence, the production problems of a beer producer, a synthetic process, are not altogether different from the production problems of a lotion or hair-oil producer; the problems of an oil refinery do not drastically differ from the steelmaker's or smelter's problems.

If there is so little difference as far as managing the production of this or that product is concerned, the question that arises is what differentiates managerial practices relative to two products. If there is little difference, why does the producer of a slow-selling product not change immediately to the production of something else substantially more profitable? Why did the buggy producer have to go out of business when the automobile gained acceptance? The answer is simply managerial inflexibility, an expression which covers a lot of ground. While the term is a simple one, the thoughts behind it are complex. First of all, it is by no means simple to break into another business. Other firms have already established themselves in the field and will do their best to keep any newcomer out. Some firms may even sell below their own cost of production for quite a while to do so. And if that method does not work, other economic pressures may be used. Even if a new firm succeeds in starting, it is difficult to get a market. And in a situation of this kind extensive advertising and other types of sales promotion can offer relatively little help. Furthermore, lack of flexibility can mean primarily a lack of money and adequately trained management personnel. If there is one critical resource in an economy, it is managerial skill, the scarcest of all resources. The planners, particularly the technical men, who were engaged in the design and planning of buggies, for instance, were not familiar with the production of automobile parts. The design-engineering knowledge, and technical knowledge in general, was inadequate.

However, if there is sufficient money available, the problems involved in shifting production activity from item A to item B are relatively simple. But as a rule, not only is money unavailable but the equipment used for the production of buggies, if not obsolete, is at least unsuitable for the production of automobiles. Plant size is usually also inadequate. And last, but not least, the patent problem cannot easily be solved. In face of all kinds of difficulties what really happens is that the owners and the managers decide to keep operating, make the best of a shrinking market, and slowly use up the equipment. Companies of this kind stay in production not because they are efficient, but because the equipment is being used up and there is little necessity to charge depreciation, except for taxation purposes. Finally, when there is no demand for buggies, the concern goes completely out of business. Usually, where powerful corporations are concerned, this kind of inflexibility does not exist. Managements who fail to keep up with the changing economy are ruthlessly forced out and replaced by vigorous men of vision and drive.

Where management is concerned, the only significant difference between production of one item and another lies in the planning phase of the managerial activity. In the first place there are two different planning activities, namely, 1) engineering and design and 2) planning the production flow. The latter is influenced by the nature of production as well as by design, interchangeability of parts, and production method. Both original planning and planning of the production flow will differ. Original planning is a matter of mechanical, electrical, or chemical engineering skill, which may, at times, also require architectural or civil engineering background. To produce an item continuously, the flow plan is developed only once. Therefore, every product will flow through the same path. But if different items are produced at different times, it is essential to develop a different production pattern for each item. Thus, for each order a different production plan must be set up.

Although in the next section some of the industrial activities are described in general terms, the student should remember that the problems of production control under different production conditions—intermittent production of custom-made items, large-scale production of standard items, and repetitive production of similar, partially standard, and partially custom-made items in either large-volume or large-lot quantities—are the most important industrial differentiating factors.

CLASSIFICATION BY END PRODUCT

A certain type of production is carried on at the place where natural resources are available. If by definition a factory is merely a conglomeration of equipment and a daily gathering of workers where production is directed by management, then mining is no different from any other type of production. In the case of mining industries, or other extractive processes, the factors of labor and capital are applied to unearthing or extracting the product in its original form.

To give information about production processes by which various items are produced, a description of some representative industries is made with the purpose of acquainting students with production that is not manufacturing in the strict sense of the word. This is emphasized here because most textbooks speak of the manufacturing industries, thereby creating the impression that production and industrial management are concerned merely with manufacturing problems or with assembly. Obviously, each industry has its own production problems, yet the problems of one industry are similar to those of any other.

Coal, Lignite, and Coke Industry

Coal and lignite are mined (that is, produced) primarily for fuel but also for chemical purposes. Coal mining is closely associated with by-product utilization—a chemical process. Good-quality coal depends little on the excellence of production or management, but primarily on the quality and richness of the earth. For chemical purposes lignite is just as valuable as high-quality coal. This is particularly true where the lignite is rich in bitumen, making it suitable for briquets or synthetic motor fuel. The efficiency of mining operations depends primarily on the excellence of the technical devices used in the process as well as on the position of coal deposits in the earth, rather than on specific managerial skill. Also, the profitability of coal mining is largely dependent on the waste utilization, as well as on the marketing costs. High-cost operations do not, however, prevent profit making if the quality of the coal commands a correspondingly higher price.

Since the cost of production depends on the relationship between mechanical devices and the various geological and geographical factors, production efficiency is largely influenced by the depth and pitch of workable seams. The interrelation between mechanization and geological features is obvious. The higher the pitch and the greater the slope and depth of the workable seams, the more difficult is the effective utilization of mechanical devices. By the same token, choke damp, water seepage, geological faults, and time required to and from the face of the pit become more serious as the depth of the seam increases. Lignite production can be much more efficient because deposits are closer to the surface and make possible open-pit operations, which are safer and more efficient than deep mining.

Down in the mine, production and operating efficiency depend largely on the availability of appropriate equipment (heavy and light drill hammers, pneumatic mining hammers, undercutting machines, coal hewers, and chain and pillar coal cutters). Internal production efficiency must be accompanied by efficient production on the surface. Thus, above- and underground transportation facilities must be available. Sorting and screening devices and automatic and power-driven loading and unloading machinery, as well as various types and sizes of boring machines, must be employed. In addition, the mine must have such auxiliary equipment as water-pumping, ventilating, and compressed-air systems. Whereas in deep mining large-scale mechanization is not always possible, open pits can be exploited more economically when thick deposits lie close to the surface. There endless-chain cutters or steam shovels can dump coal directly into moving cars.

In mining, the human element has been largely replaced by machinery. Mechanization has facilitated production and eliminated the necessity for lengthy training of both workmen and supervisory personnel. Use of equipment has considerably increased productivity of labor. Current productivity of mining operations is therefore mainly due to technological progress rather than to improved management.

Coal is the raw material of gas production. Depending on the purpose of the plant, either the gas or the coke, a residuum, is a valuable by-product. The former is used in chemical plants, the latter in iron and steel mills. (Some steel mills produce gas and chemicals as a sideline.) The most important coal by-products are ammonia, which contains nitrogen; benzol and its homologs; and tar. Ammonia in its refined form is used as a fertilizer; benzol is broken up into its chemical components and when purified can be used in place of gasoline. A large number of chemicals, of which the most important are pitch and all sorts of impregnating oils, are extracted from tar.

IRON AND STEEL INDUSTRY[2]

The word "industry" here refers to many interrelated activities as shown in Fig. 2-1. The iron ore, the raw material of the steel industry, is extracted through a mining process. The steel is produced in stages: 1) iron smelting, 2) steelmaking, 3) rolling, and 4) machining. There are, of course, many intermediary processes, such as alloying, forming, and tempering. Efficiency requires that most stages of iron and steel production should be integrated. Thus, a steel firm may be engaged in every phase of steelmaking from extraction of raw materials to the refinishing process. Nowadays rolling mills are connected with blast furnaces in order to economize in the use of fuel. Thus, the product can go from one stage to the next without too great a loss of heat. It is a common practice to pour the molten metal, via converters, into molds and let it harden slightly. The still-hot ingot is sent to the soaking pit to acquire uniform temperature and from there directly to the rolling mills. There it is converted into bars, beams, sheets, wire, rails, and dozens of other industrial products. The fuel saving resulting from the integration is tremendous and is one of the many reasons why steel companies are usually large; plants engaged only in one stage of iron and steelmaking would not be sufficiently efficient to compete with the large integrated mills.

The by-products of steel production are useful to the chemical and countless other industries. For instance, the operation of a blast furnace, such as the one shown in Fig. 2-2, supplies large quantities of blast-furnace gas, which is piped through long-distance mains directly to the point of use. During the blast furnace operation a considerable amount of dust, containing a large percentage of pure iron, is recovered. Slag floating on the top of the molten metal is used to make cement, bricklike compounds valuable as building material, railroad ballast, and aggregate for concrete and mortar.

Standardization of steel quality and simplification of product lines permit the elimination of small-batch production through joining together many customers' orders. While this causes a considerable amount of difficulty in production control, it is worthwhile from the point of view of cost reduction. Without such production control methods, it often would not be worthwhile to recover wastes so valuable in chemical production. Just as the small-scale neighborhood butcher is less efficient than the huge meat-packer, so a large company in the iron and steel business is efficient because of the waste utilization, which may cover a large portion of running expenses. Furthermore, without standardization and development of production control methods, a relatively continuous flow of production could not be achieved.

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[2] An excellent discussion on an integrated steel mill operation can be found in A. E. Lawrence, "Production Planning for an Integrated Steel Plant," *Iron and Steel Engineer*, May, 1960.

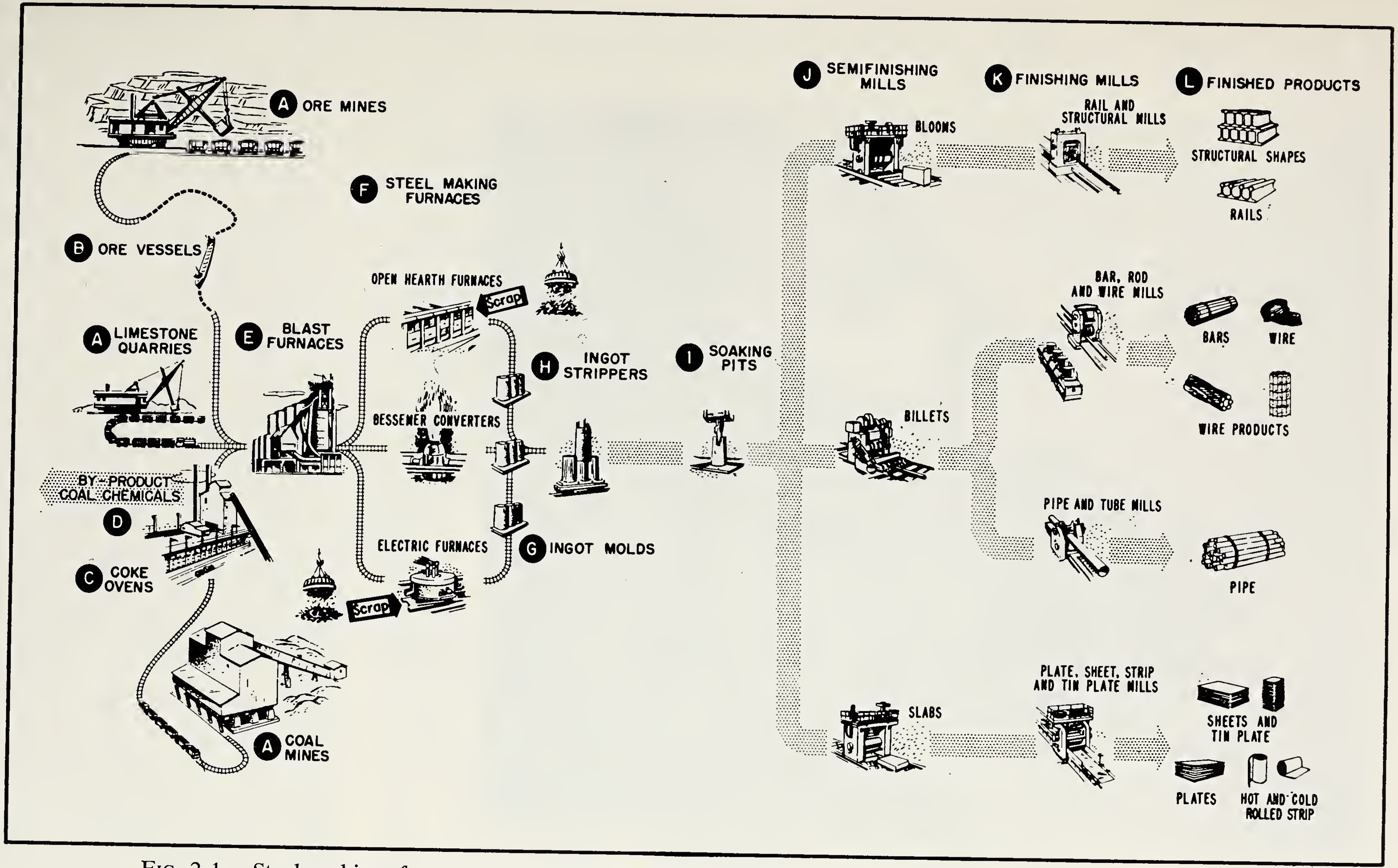

FIG. 2-1. Steel making, from raw materials to finished products. (Courtesy of United States Steel Corp.)

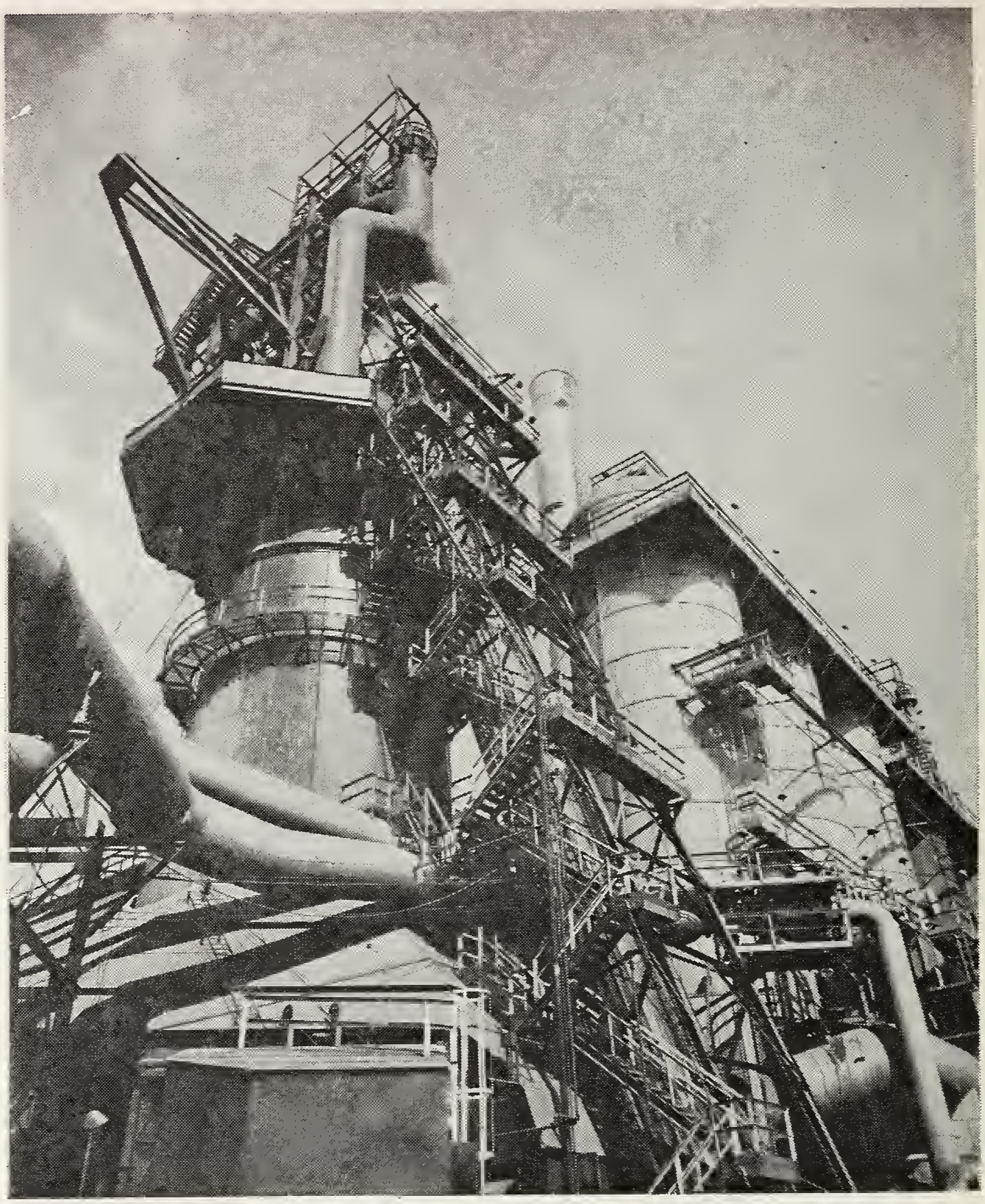

Fig. 2-2. Blast furnaces such as this produce iron which is later added to the open-hearth furnaces to make steel. (Courtesy of United States Steel Corp.)

The Machine Industry

The importance of the machine industry cannot be overemphasized. In the introductory section of this book industrial productivity was largely attributed to the nation's capacity to produce and employ large quantities of capital goods. Where the preponderance of productive work centers around machine processes, production of equipment plays an extraordinarily important role in industrial progress. The function of the machine-producing industry is therefore to supply the equipment necessary to keep the economy in high gear. Thus, a breakdown in this field could be disastrous. Automation, the newest type of mechanization, is based primarily on the excellence of the machine-producing industry. This industry provides the rest of the economy with cheap, efficient, and high-grade equipment and contributes largely to technological progress. It is basically a combination of the manufacturing and assembly-type industries and is engaged in both continuous and intermittent production. Manufacturing produces the parts, and assembly puts them together. Even though a preponderance of the products of the machine industry is special-type machinery, many component parts are of standard design (screws, bolts, nuts, gears, roller bearings, and handwheels).

THE CHEMICAL INDUSTRY

In a highly generalized sense one speaks of chemical production if the process through which the raw materials go alter the chemical characteristics of the materials themselves.

Since there are in every industry a few minor types of chemical processes, it is difficult to determine just what does belong to the chemical industry. If we emphasize chemical processes (the products of which are not necessarily chemicals), then we may as well classify a large number of metallurgical and electrotechnical processes as being a part of the chemical industry inasmuch as they all require some degree of chemical treatment. Similarly, rayon, nylon and orlon production could conceivably be considered not only as part of the textile industry but also as part of the chemical industry. The important branches of the chemical industry are the following:

1. Heavy chemicals (hydrochloric and sulfuric acids, soda, carbides)
2. Artificial fertilizers and insecticides (petrochemicals)
3. Aniline, mineral dyes, and lacquers
4. Explosives (nitroglycerin, cyclonite, atomic and hydrogen explosives)
5. Pharmaceuticals (aspirin, antihistamine, epinephrine)
6. Detergents; cleaning and polishing fluids and compounds
7. Ether oils, alcohols, and aldehydes
8. Perfumes and cosmetic supplies
9. Photographic chemicals and sensitizing products (mylar polyester film, computer memory tape, color-picture film)
10. Vaccines for conquering diseases (Salk vaccine)
11. Plastics of all kinds (celluloid, Bakelite, resin, galalith, polyethylene, vinyl, phenolic resins, Teflon, delrin, polystyrene)
12. Textile chemicals (nylon, perlon, orlon, rayon, decrone polyester fiber, acrylonitrile, acrylic fiber, lyra spandex fiber, caprolactam)

Yet where processing is concerned, even this classification is controversial. Pharmaceuticals often involve simple chemical processes (analytical) in which the components undergo no physical changes. In the strictest sense, this is not really chemical production. Also, products such as soaps, cleansing materials, perfumes, and cosmetics often involve nothing more than mixing of various chemicals by mechanical means rather than affecting chemical fusion. Similarly, oil purification might have chemical aspects, yet production of oils and oil by-products is a simple distillation process and has nothing to do with chemistry—except that the raw materials are chemicals. Hence, many firms classified as chemical plants scarcely differ from companies engaged in the production of paper, sugar, rubber, or potash salts.

The chemical industry employs almost as many different equipment and processing methods as can be found in the mechanical industries. Refinement in methods and increases in production volumes have precipitated a high degree of specialization among chemical plants as well as in auxiliary equipment; but changing from the production of one item to another would, despite a large degree of standardization as far as equipment and processing methods are concerned, necessitate scrapping some equipment altogether. (See Fig. 2-3 for a typical chemical plant operation.)

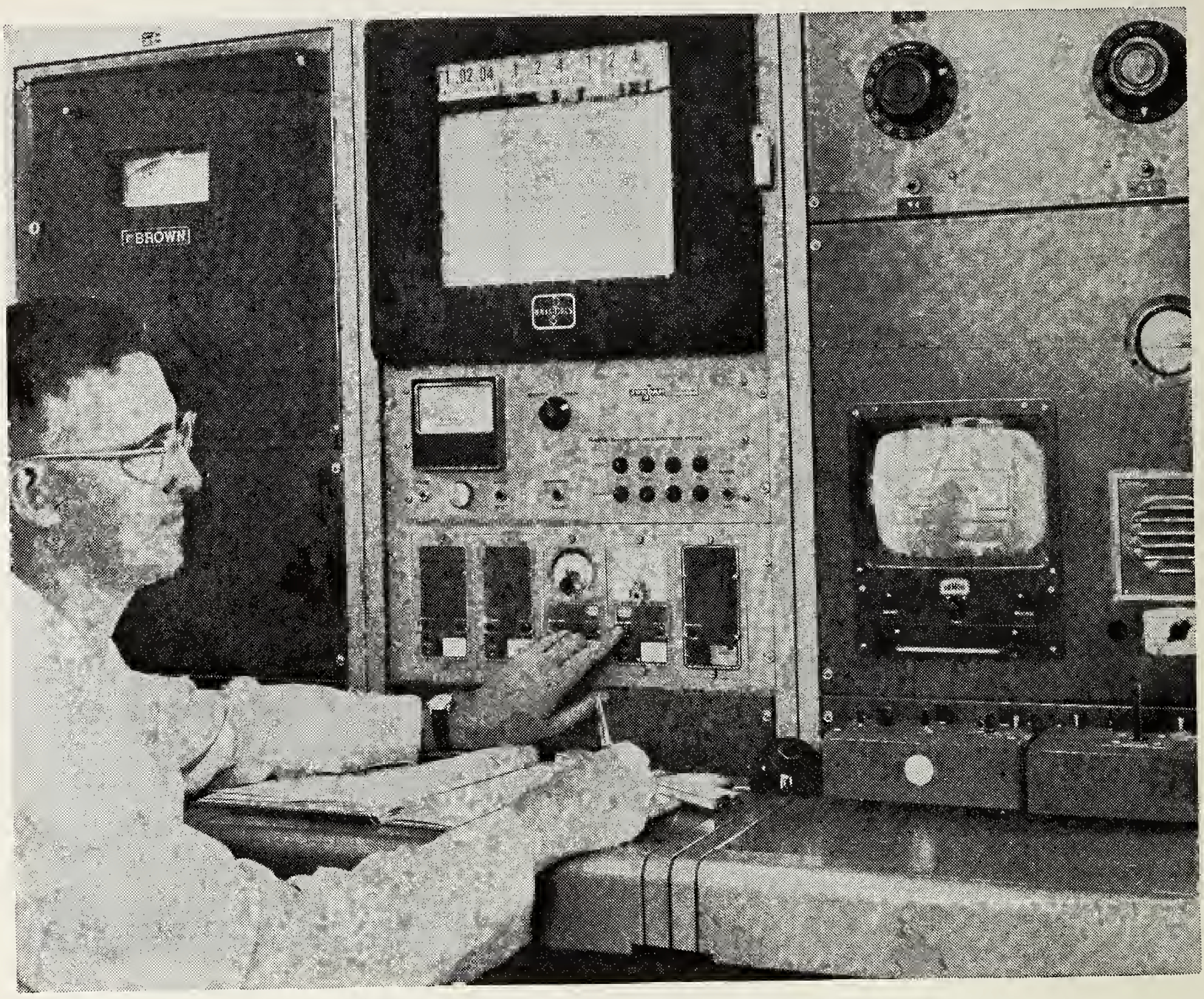

Fig. 2-3. A typical chemical plant operation. Readings are checked on various gages and valves and material-handling devices are adjusted by remote control. (Courtesy of Union Carbide Corp.)

Where it is feasible, in chemical plants, heavy labor and highly repetitive jobs have been mechanized. Generally speaking, chemical industries utilize large vats, mixers, tanks, and buckets in which chemical processes take place, in addition to the handling devices and other plant facilities such as ventilating and air-purifying systems.

THE ELECTROTECHNICAL INDUSTRY

The electrotechnical industry is a branch of the machine industry, although it is naturally much easier to produce a small metal piece than an intricately curved machine part. There are two main groupings within the industry: 1) electric machines and appliances and 2) equipment for electricity generation. The former are tested in laboratories, then produced in large scale for the open market. The latter are usually customer-production items produced through intermittent manufacturing methods. Enterprises within the industry manufacture, assemble, and test cables, electric motors and coils, rubber parts for electronic apparatus, transformers and transistors, lamps, electricity and water meters, porcelain, switch gears, dynamos, small accessories, heating and cooking devices, radios, television sets, electronic computers, spaceship parts, and missile components.

The high degree of specialization among producers allows extraordinarily efficient operations. While metallic and nonmetallic parts are purchased from other industries or manufactured as a sideline business, the assembly and testing phase of operations is the "real" electronic industry. The plant layout and arrangement of machinery is based on the natural progress of the assembly. Workplaces are frequently connected by a conveyor system; or the semifinished parts and subassemblies are dealt with on long assembly benches. In this case the platform of the bench moves at definite intervals from one operator to the next. (Obviously, the individual work stations are carefully time-studied and synchronized with one another.) After the assembly process, the completed electronic devices pass, as a rule, through testing stations and are painted and dried while moving toward the storerooms. Those plants and buildings which are related to one another are so grouped as to feed into and take away from flow systems efficiently. We are dealing here with the assembly method as practiced by the machine industry, although the types of skill needed are different.

Production in the electronics industry requires a high degree of labor skill and specialization. This high degree of specialization allows a cheap rate of operation and encourages mass consumption. Most tasks require precision and finger dexterity, yet so little physical exertion that women can be successfully employed as shown in Fig. 2-4.

The growth of the electronics industry is attributed to its reasonably priced products. It started out with simple designs and cheap and fully interchangeable standard parts. Cheap repair and maintenance were also some of its characteristics. When power-producing equipment became widely used, a number of factors helped to place output of the larger type of electrical devices on a mass-production basis. Despite the fact that most turbines, trans-

FIG. 2-4. Assembly of stereo FM tuners. (Courtesy of Zenith Radio Corp.)

formers, and special types of power-generating devices are custom-built, standardization of parts and the volume of demand, beginning with the electrification of the machine and most of the other industries, permitted large-scale production. An additional boost came from the rapid development of the transport and communication industries. Electricity is the essence of telephone and telegraphic communication and business communication in general. This places the power-equipment industry in a key position next to the machine-producing industry.

THE TEXTILE INDUSTRY

The textile industry (fiber preparation, carding, spinning, knitting, weaving, dyeing, finishing, and clothes making) is based on the refinement of methods inherited from past civilizations. Mechanization started with Kay's flying shuttle, which permitted weaving of wider cloth at a faster rate. This invention provided the basis for a more continuous flow from one stage of production to the other. Thus, spinning and weaving were then taking approximately the same amount of time, whereas formerly spinning was faster than weaving. Mechanizations in weaving techniques then made spinning inadequate until Hargreaves' invention of the spinning jenny. Arkwright's water frame again brought the two production phases in balance as well as improved the strength of the thread. Crompton's mule spinner improved both the water frame and the jenny. Now, spinning and weaving were out of balance again. Finally Cartwright's power loom was improved to such a degree that again weaving could keep in step with the output of spinning. In other words, the textile industry gradually developed. Ancient skills were transferred to machinery. As a result, both woolen yarn and cotton threads became of uniform width and strength, since production no longer depended on the sensitivity of

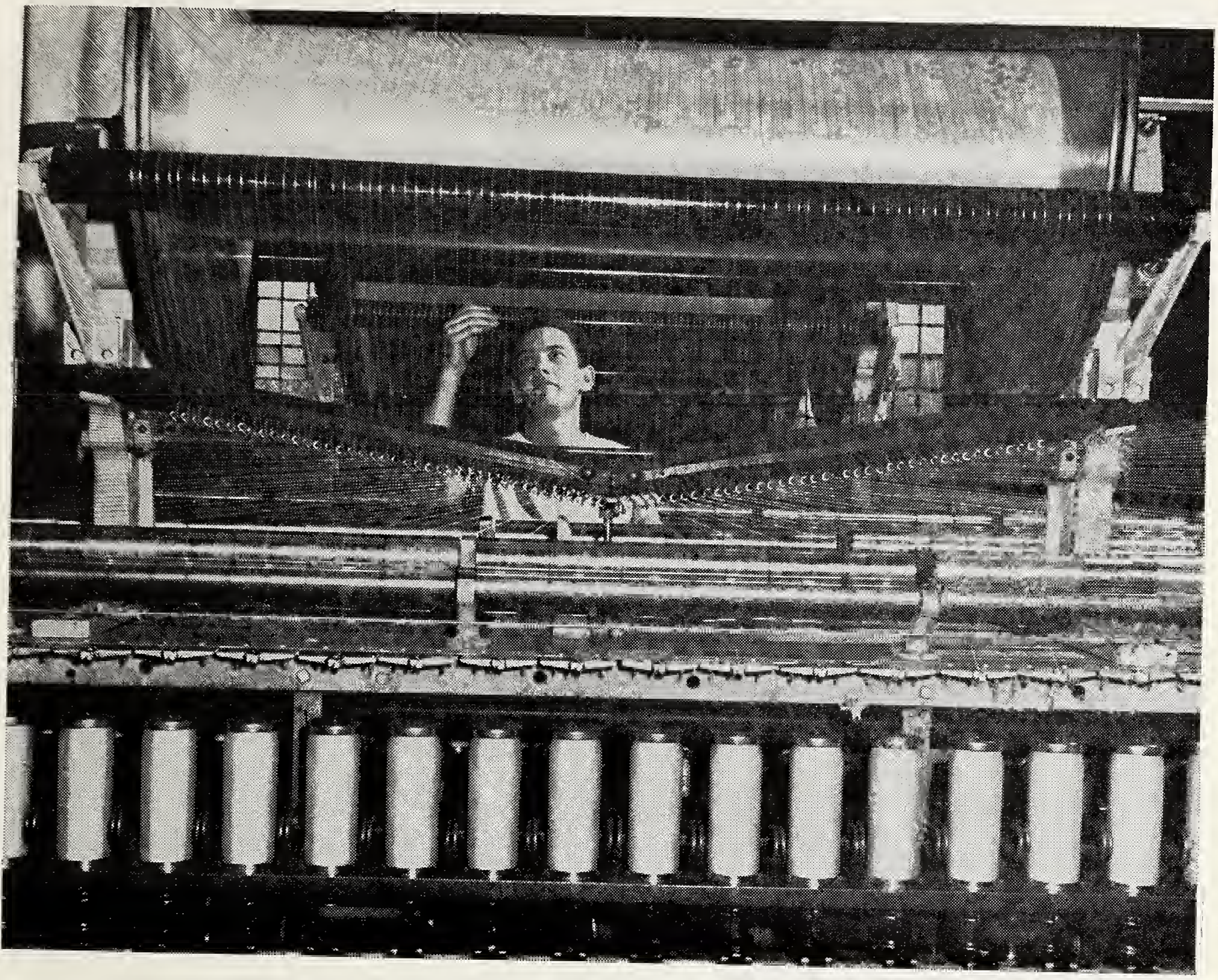

Fig. 2-5. Ply-twisting of filaments onto spools. Cords are then woven on textile looms into sheets of fabric. (Courtesy of The Firestone Tire and Rubber Co.)

human hands. Hence, mental and physical skill were built into machines and to a large extent permitted the elimination of human labor.

Modern textile production, just like iron- and steelmaking, takes place in stages. First the thread is produced, as shown in Fig. 2-5, then it is made into cloth or fabric through either weaving or knitting. The resulting material can be dyed and transferred into men's or women's apparel through manufacturing or used in other manufacturing processes.

All the above stages utilize different equipment (machine tools or hand tools). Yet despite a high degree of mechanization and labor specialization, the efficiency of the industry leaves much to be desired. This is primarily because of the unfortunate influences of fashion, although clever production control techniques and plant layout arrangements tend to counterbalance inefficiency caused by fashion-dictated small production lots. Those branches of the textile industry which deal with a standardized consumer demand (underclothing for men, shirts, stockings, socks, handkerchiefs, sheets) are more efficient than those exposed to a fluctuating demand. Rising efficiency can be attributed to work simplification in general and to eliminating lost time between successive operations, reducing fatigue through rest pauses and coffee breaks, and improving working conditions (lighting, heating, and ventilation in particular). But above all, rising efficiency can be attributed to technically improved production equipment.

Attempts to improve production efficiency have also centered around standardization of materials (classification of dimensions, color tones, color fastness, thread strength and count, weave types) and production control methods which have made possible production of large volumes despite the predominantly intermittent nature of production in the finishing stages.

In the textile industry it is not as easy to combine the various phases of production under one roof as in the steel industry. Specialized and independent operations in weaving or yarn production, dyeing, and manufacturing are well justified by drastically different production processes in which only the raw material is the common element.

COMMENTS ON INDUSTRIAL PRODUCTION

The great multiplicity of production activities permits the examination here of only a few representative industries. Most industries resemble those already described, although natural gas and oil production are in a class by themselves. Machinery is nothing more than a "skill executed mechanically." In the chemical industry, the equipment is essentially nothing more than a container like the pots and pans or pressure cookers used by housewives. Chemical components are placed in these vats and mixed with other chemicals. The chemical transformation (which is invisible) takes place under pressure or heat. Beer brewing and alcohol production are familiar yet quite simple chemical processes. Ingredients are changed chemically from starch to sugar and from sugar to alcohol through a simple chemical process. Taste is given by other ingredients such as hops or fruit extracts. All these processes involve the use of equipment in one form or other. The equipment can be used either as a holding or container type of device or as a device which does something to the raw material. Whether the equipment involves an operator or works automatically is of minor importance. The fact is that equipment is used in production. In an extractive production process (for example, picking grapes), the basket is used as a holding device, and the scissors are used as cutting tools. The nature of equipment (large or small, special or multipurpose, simple or complicated device) is of little importance. The equipment simply facilitates or enhances human productive capabilities. The more equipment is used and the better and more scientifically has the nature of equipment utilization been planned, the greater can become the productivity of labor.

The use of drilling equipment in oil or natural gas production appears to be different from a drill press operation in a manufacturing plant. Yet only in size and technical capabilities does the big oil drill differ from the small drill press. Either one of these two drills must be operated by someone; otherwise, neither is of any use, for human skill in using the equipment in question is necessary. Generally speaking, equipment is only as good as the skill of its operator. While the problems arising out of the use and application of equipment vary in different fields of production endeavor, certain problems faced by various enterprises in different fields seem to resemble one another. To discuss common industrial problems and differences between them in a classroom is almost impossible; impossible if we want to discuss specific problems. But discussion is always possible in a highly generalized sense. Certain types of problems occur in every industry and in every industrial setting—regardless of the nature of the production process, the usefulness of the product in question, or the type of equipment employed. If we know how to solve problems in one industry, we can, with some practical experience in the firm in question, solve them in other industries also.

CLASSIFICATION BY PRODUCTION QUANTITY

The differences in various production activities lie not in different management practices, but in the nature and use of "different" equipment. These differences in use must be reconciled with various management objectives.

Supervision is no different whatever is being produced. Therefore, the techniques of planning, organizing, directing, controlling, and coordinating the efforts of workers are uniform in most industries, though minor differences may result from the need for different supervisory experiences and backgrounds. The supervisor always supervises people; the equipment and materials involved are incidental rather than principal factors in his work. Only the planning phase, particularly that of engineering planning, differs from industry to industry and from industrial enterprise to industrial enterprise. Yet these differences are less significant than commonly supposed because the people who are hired are bound to have been trained in different fields of engineering and these differences in human background cancel out the differences occurring in different industrial settings.

While it is true that the specific processes performed—the type of industry and its product—are the bases for differences as far as management of production activities is concerned, it is primarily the size of the production volume in relation to cost and delivery promises which imposes problems. This is readily apparent when a producer who makes one single item in huge quantities is contrasted with another who makes a multiplicity of different items in small quantities. The size of the production volume creates different headaches for production management. The general nature of the problem can be compared to repairing hundreds of different makes, models, and styles of cars per month as opposed to repairing only brakes on 1963 Chevrolets. If in the former case we have to meet different repair needs, that is, customer specifications, the problems involved are usually more complicated. Repair only of brakes on 1963 Chevrolets implies 100% standardization of parts and components and a patternlike method of production. The deliberate choice of uniform materials, sizes, and dimensions permits the use of identical production processes. That production methods can be standardized is one of the initial arguments in favor of increasing output.

Large volumes make possible the application of the latest technical improvements, scientific management methods, and production control techniques. In turn, the reduced costs of production will, if accompanied by price reduction, encourage increased mass production. The aforementioned standardization is then mainly, if not entirely, the cause and effect of mass production and consumption. But standardization is not a goal in itself—it is merely a means to an end. Volume production is the answer to low-cost operations, large-scale methods of production, efficient line layout and conveyor systems, special tools and equipment. Thus, low costs of production, competitive pricing, and mass consumption go hand in hand. Unless the one is attained, the others are unattainable. And standardization of products and processes plays an extraordinary role in the attainment of production efficiency and its concomitant, low-cost operations.

Although volume production was emphasized, it must be apparent that in some areas mass production is not possible. The nature of demand, differing consumer wishes, and product specifications call for specially designed products and production processes. Nevertheless, wherever possible, standardization will contribute to the lowering of the costs of production and can precipitate rising sales. Of course, standardization in itself cannot remedy everything, but it may be the first step in creating a continuous flow of production, improved production control techniques, and easier and faster ways of doing productive work at individual operations. Standardization of methods can also contribute to better utilization of available manpower, since required skills call for less training and human effort.

Small-scale production is obviously different from year-round production of uniform items. Because of the wide difference in jobs, it does not pay to use specialized equipment. Machinery will then be used with less speed, but with greater versatility. Since employees will do many different jobs, labor specialization becomes more difficult and equipment cannot be logically ordered. This does not imply that in small-scale production no attempt is made to shorten the production cycle through plant layout and other systematic methods; it merely means that such an arrangement of equipment is more profitable in large-scale production.

The problems of production for products of the brand-name variety will differ because the quantity which must be made is considerably larger. By the same token, custom-made products are usually made in small quantity. Small-scale production will pose different, but by no means less complicated problems.

INTERMITTENT, REPETITIVE, AND CONTINUOUS PRODUCTION

Since volume is admittedly the most important production consideration, it stands to reason that industrial problems center around production volumes. Large-scale production tends to be on a continuous basis. In contrast to this, small-scale operations are usually intermittent. Nevertheless, it is possible to produce standard items on a large scale in some sort of intermittent fashion. These products are usually produced on a repetitive basis and require special methods to control the flow of production.

Despite the knowledge that production processes can be classified on the basis of output as intermittent, continuous, and repetitive, we may still be hazy about exactly what is meant by these terms. Let us assume for the sake of clarification that we are a small auto repair shop operating with four to five employees. Our product is “repair.” Since every job which comes into the shop is different, it is not possible to set up a specific production line for repair purposes. In other words, it is unthinkable to send the part down a production line. Hence, we have a standard plant layout suitable to the repair of all kinds of cars. The product moves from certain sections to certain other sections of the plant depending on the nature of the repair and equipment needs.

No production plan is set up until the source of the trouble is discovered. Since each car will have different things wrong with it, the production plan is bound to be different for each. To keep the mechanics busy and to make certain that we get the best out of our equipment, it is essential in this kind of operation to keep a constant check on every man and machine. Every car must be individually routed through the production process and must have separate production schedules. In this way each car will be completed at the time the customer wants it.

By performing the planning, routing, and scheduling functions again and again as new customers come in, not only are customers kept satisfied but also the cost of production can be kept at the absolute minimum. This assures the profit of the enterprise despite its small-scale operations.

We mentioned a garage, but the enterprise could have been a large custom tailor or a machine shop engaged in the production of products ordered in small quantities to customer specifications. It is a complicated problem to arrange matters so that each customer's order moves toward completion along with the orders of dozens of others and is actually completed on the promised delivery date. A complicated technique must be used to make certain that everything moves according to preestablished plans and that nothing disturbs the orderly accomplishment of the plan. The technique which sees to it in intermittent production that everything is under control is called the order control.

For the sake of simplicity let us assume that instead of a car-repair shop, we are dealing with a car-wash enterprise. Washing cars is a standard process. The inside of each car must be vacuumed, the dashboard dusted, and the wheels, sides, hoods, and tops washed. Since each car goes through the same operations, every employee to whom a particular operation is assigned knows what to do without renewed instructions. There is no particular problem either at the start or during the production process. Thus, after the plan is set up, the layout is arranged, the flow is time-studied, and the work stations are synchronized, every car will move without further instruction. The only thing we have to know is the number of cars to be cleaned. Each car to be washed could receive a serial number, and it would be easy to determine which serial-numbered car was being worked on at any given time. This control is called serialized or flow control. Although we speak of a car-wash enterprise, the production of automobiles at a Detroit assembly plant, beer making in a brewery, and wire drawing in a steel plant can be controlled in and during the production process in a similar manner.

This brief description illustrates that problems in the various industrial enterprises can be divided into two planning phases: 1) engineering planning and 2) production flow planning (control). In the intermittent process we produce new products constantly. In continuous production, there is only one product. In the latter case the very first product goes through an elaborate engineering planning and an equally elaborate production planning procedure. Once these plans are perfected, no additional effort is spent on the production of any succeeding unit. Since the production flow is built into the plant layout, it is fairly simple to exercise control over production quantity by listing the serial numbers or keeping track of the input. Since the production cycle is determined, it is possible to foretell and pinpoint the exact location of any given serial-numbered item in any part of the plant. After the preliminary arrangements, a production process of this kind requires only a continuous arrival of raw materials. The main task of management is to make certain that no interruption occurs in the flow of production. If this flow continues, the cost of production will normally be low. Conversely, interruptions become extremely costly. Hence, the main function of flow and/or serial control is to keep the production line moving at a predetermined rate.

We have items which can be produced in large volume and plant machinery that is capable of producing considerably more than the market can absorb. How do we handle a situation of this kind? To illustrate the repetitive production control system, let us assume that we are a cosmetics or paint producer. Our production process consists primarily of mixing different chemicals. For this reason we use a large amount of container-type equipment. The production process is the same whether we mix face cream or toothpaste. Despite minor variations in process, the general flow followed by the raw materials in the production of different items is the same. So we determine the production flow only once. Since the production plan is established only once, the planning process resembles that in continuous production.

However, since we do not need as much toothpaste as the equipment—if in continuous use—is capable of producing, we use the same equipment to mix several other chemicals also. The production of toothpaste is stopped and the equipment is cleaned and prepared for the production of something else. In this way production now resembles intermittent production. Although we produce a large volume year in year out of the same item, we periodically interrupt the production flow. However, control over the production of one item and the production of the next one is simple, because we follow the same pattern which we established at the time the job was first performed. Companies which are engaged in repetitive production make goods repeatedly in quantities as required. When their stock is depleted, the production of a predetermined "economic quantity" is scheduled. Until the next run, the equipment is used for other purposes. It should be noted, however, that this equipment is not 100% versatile in repetitive production. It can produce only a few selected items.

Parts suppliers to the automobile industry are found to be engaged in repetitive production. The automobile firms usually give "open-ended contracts." This means that no specific quantity is agreed upon and demand must be met at relatively short notice. Since the parts manufacturers can not sit and wait when the automobile business is slow, they do something else with their available plant capacity until a new release comes along. So the equipment is used for several different purposes. Most suppliers to brand-name producers of television sets, cars, and electronic devices are engaged in repetitive production.

So far as control is concerned, repetitive production bears similarities to both intermittent and continuous production.

SUMMARY

The Factory System of Production

During the last fifty years or so great changes have taken place in the methods and scale of production. New problems have replaced old ones. To meet human needs, a high degree of specialization has developed, resulting in an obvious industrial interdependence. Hence, few industrial enterprises produce all their needs themselves. Instead, the product of one industry is the raw material of others.

The handicraft system of production was replaced by the domestic system. The chief difference lay in the planning, control, and direction of production. Under the domestic system the craftsman became a wage earner and was supplied with tools and raw materials by a merchant-entrepreneur who told him when to produce, what to make, and how to make it. The entrepreneur did none of the manufacturing himself; he only supervised production and assumed the risk. The domestic system was common in all lines of industrial activity. The early part of the eighteenth century and the new inventions of the era changed the production system, which was replaced by the factory system.

From now on work was performed in factory buildings or in other places where facilities were available. There were two groups of people engaged in production: capitalists and wage earners. The former were also managers—or they hired professionally trained managers—who planned and directed production.

Classification of Industrial Production

Basically there are two groups of industrial enterprises engaged in production. The first group is responsible for the availability on the market of natural goods such as coal, ore, timber, fish, and crude oil. The distinguishing feature of primary industries lies in the fact that they are engaged in extracting natural resources and supplying the finishing industries with items taken direct from nature. While the primary industries are engaged in the extractive production process, the finishing industries are engaged in analytical, synthetic, fabricating, and assembling production processes.

Natural goods are derived from land (earth), water, and air and are in the form of crude oil, coal, ferrous ores, timber, and fish products, to mention only some of the more important items. However, gases taken from the air may be important raw materials as far as certain chemical companies are concerned.

The goods of the primary industries are further processed in finishing industries. The chemical industry may take apart and recombine in different ways some of the familiar natural goods, such as natural gas, petroleum, salt, limestone, and coal. Thus, for instance, when ethylene gas (derived from natural gas) is subjected to extreme heat and pressure, it becomes a solid substance—plastic. Iron ore, via the blast furnace, becomes iron and is subsequently converted to steel or, when combined with other elements, specialty steel with special properties. The steel in turn can be turned into other products after it has gone through several different production processes. Fabrication will change the metal into parts which, when assembly has put them together, become products the ultimate consumer wants: automobiles, refrigerators, and typewriters.

How one industry furnishes raw materials to other industries can be illustrated by the meat packing industry, where the hog carcasses[3]

> follow a route which branches into an astonishing number of paths, producing meat, and manufactures of meat; bones, from which are made hard white articles, such as knife and brush handles, charcoal, bone black, chicken feed, and fertilizer; fats, bases of soap and many other things; certain useful chemicals; and offal, which is made into glue, gelatine, grease, and fertilizer. The hides form the raw material of a chain of plants, starting with tan vats, from which the leather produced is split into two or more layers, and worked through many processes to form many grades and kinds to go into the plants producing shoes, straps, handbags, gloves, pocket cases, and a thousand other articles.

Difficulties in Management of Various Production Activities

Most enterprises are similar as far as the management of their production activities are concerned. Supervision is the same activity regardless of the nature of the production; so is management of production in general. Executives tell supervisors what to do, and supervisors, in turn, tell the workers what to do and how to do it.

Planning activities, however, tend to differ, even where there is a great deal of production similarity. Engineering problems will take different forms and require differently trained personnel, but the training background and experiences of these specialists will take care of these differences. Production planning and control, just like supervision, has certain universal rules. Thus, the techniques of production planning are the same provided we are dealing with comparable production volumes. Production of standard brands on a large scale to meet mass demand will cause headaches different from those caused by the production of nonstandard items on a small scale.

Where production planning is concerned, we must first know whether the plant is producing large or small quantities and in which intervals. If demand is relatively continuous, production may be gaged to demand conditions and production control's main task is to maintain the flow of production at a desirable rate. This is then called flow control. If the goods the plant is turning out are not perfectly identical, each unit may be given a serial number which will identify each unit of output. By keeping track of serial numbers, minor differences can be built into the items without interrupting the continuous flow of production. Where differences between output units are more substantial and equipment is used for a multiplicity of purposes, a combination of flow control and intermittent-production order control may be successfully applied. When orders are always different, small-scale production is bound to be practiced and each order is planned separately and controlled individually through the production process. The latter is the so-called order control.

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[3] S. H. Bunnell, "Industrials: Their Securities and Organization," p. 77; reproduced from a Merrill-Lynch letter to the customer.

QUESTIONS

2-1. How does modern production differ from handicraft?

2-2. Does production of ancient times differ drastically from production of today? If so, how?

2-3. Is it true today that labor, capital, and materials are combined with one another in the same way as they were in the past?

2-4. What distinguishes a chemical plant from a steel mill?

2-5. Does the function of "supervision" differ from a forge shop to a candy factory?

2-6. It is said that the proper application and combination of land, labor, and capital results in production and in a product. In line with this reasoning, is coal or iron-ore mining different from any other type of production?

2-7. If you were working in a plant, what skill would you need to accept supervisory responsibilities?

2-8. What skill do you think the foreman in a coal mine should have as opposed to a foreman in a machine shop?

2-9. Provided that you are a trained production control expert, could you plan production in a chemical plant as well as in a machine shop?

2-10. What distinguishes one production enterprise from another?

2-11. It has been stated that a factory is a conglomeration of machinery and a daily gathering of men to change the form and shape of raw materials. What about factories where no machinery exists? Can this be called a production enterprise?

2-12. What are the distinguishing features of chemical production? Could any good leader (let us assume that he was a platoon leader in the army) supervise chemical operations without extensive training in the chemistry of the product in question?

2-13. Would there be a great deal of difference between scheduling production in a coal mine and in an automobile plant?

2-14. What do we mean by a) continuous production, b) repetitive production, and c) intermittent production?

2-15. Production can be controlled by serialized control techniques, order control techniques, and hybrid control techniques. Try to explain the relationship between these production control techniques.

2-16. What difference does it make whether a large volume of standard items or a small quantity of nonstandard (custom-made) items is produced?

PROJECTS

2-1. List a number of industrial enterprises engaged in a) continuous production, b) intermittent production, and c) repetitive production. d) Explain why you think that the company in question is in the type of production you claim it is, basing your conclusion on the product involved. (Regardless of the knowledge you possess, you should be able to decide whether the product in question consists of standard and interchangeable parts.)

2-2. It has been stated that managerial skill is transferable. If you were to schedule production in a chemical plant where equipment consists of some sort of mixer and huge vats, what information would you need to set up your production schedule? Explain.

2-3. List and explain the characteristic features of five important industries and try to visualize the differences a manager might encounter in each of them.

2-4. Visit an industrial plant of your own choosing and list your observations as to the following: a) the product involved, b) the method of production, and c) the employee skill needed at the various stages of production. Observe the line foreman as he supervises his subordinate employees. Find out from your guide how employees always know what they have to do at any given time. Follow up the route of a product from start to finish. If possible, choose a company engaged in the production of an item which can be visually followed up. For instance, certain chemical processes are not easily observable.

2-5. List carefully the factors of production used by three companies, that is, their raw materials, equipment, and type of labor skill.

CASES

2-1. Amalgamated Iron and Steel, Inc.

Amalgamated Iron and Steel, Inc. is a large producer in the iron and steel industry with assets amounting to millions of dollars. The preponderance of company facilities are located in or near Chattanooga, Tennessee; Gary, Indiana; and Pittsburgh, Pennsylvania. The combine was created in the midst of the Depression through the consolidation of many small companies engaged in various phases of iron and steel production. The member companies of Amalgamated Iron and Steel, Inc. were at that time on the verge of bankruptcy.

Although today most of the member companies have lost their identities, the history of the company lists several dozen member companies. These enterprises were profitable producers of steel products before the Depression of the 1930s. Starting with the Depression, most of them operated in the red. Even those which could break even were finding themselves in a financially precarious position. At the time the combine was created all member companies were in court. The bankruptcy court usually recommended to the creditors some sort of settlement. Presiding judges indicated in most cases that the creditors would be better off accepting a modest settlement than forcing the companies involved to auction their plant facilities. There was a clever lawyer who contacted every court dealing with a steel company bankruptcy case and engineered behind the scenes the creation of a new company which would operate under the name of Amalgamated Iron and Steel, Inc. He and his associates were willing to pay 15 cents on the dollar to each and every creditor. The lawyer succeeded in creating a group of debtor iron and steel companies and negotiated collectively with the chairmen of the various creditor committees.

The chairmen of the creditor committees accepted the lawyer's proposition, but only after a prominent judge recommended the advisability of the arrangement. The lawyer who engineered the merger became a major stockholder and the chief executive of the newly created corporation. He, in turn, appointed each former president in an individual company as a plant manager or a vice-president in charge of production. The various plants were then called by different letters of the alphabet. Those plants with more than 250 employees (in normal years) were to be led by vice-presidents, smaller ones by plant managers.

The situations in the various steel companies bore a great deal of similarity to one another. All of the companies were losing money. Some of them operated profitably only on paper; under a normal cost accounting procedure, every single one of them operated in the red. Thus it was true that alone none of the member companies could have functioned profitably under the then prevailing economic depression. Collectively, however, the corporation could run efficiently.

Efficiency in production demands that employees and facilities be kept steadily busy and that the factors of production be wisely utilized. Despite the fact that during those poor times some of the companies did not charge depreciation in cost calculations, their prices were often still higher than those of competitors. When the goods were sold at competitive prices, the losses in some companies were quite substantial. For such losses company management was usually blamed. Yet this was not quite just. Although some of the owners, or top managers, of the companies were conservative and a few of them downright incompetent, the sales problem was international rather than domestic. After a considerable study by a consulting firm, it was decided that some of the production facilities could not be efficiently operated. Some member plants with excellent facilities, however, were terribly mismanaged. Disregarding the sales problem, it was obvious that success in production depended not merely on equipment and employees but also upon know-how and skill of management to organize the factors of production in such a manner that incurring costs were kept low and output per man-hour of labor high. Although plentiful under the circumstances, the factors of production must be treated as "scarce factors"; none should be allowed to go idle or be wholly or partly unused. While it was not unusual during depressed economic conditions for equipment to stand idle, among these companies idleness was a considerably more severe problem than among other iron and steel companies. This could be attributed partly to the fact that methods and production control systems rather than the plant facilities were obsolete, and as a result production was not up to par in the qualitative sense. Also, despite excess capacity, most delivery promises were broken because orders were lumped together and different delivery dates were disregarded. While enlarged production runs meant sizable savings in fuel and thereby reduced operating costs, the broken delivery commitments usually offended the customers who could, during such hard times, rightly be selective. Thus the sales problem also could be attributed to conditions precipitated by poor management rather than by the depressed economic conditions. This does not, of course, imply that the depressed conditions were not primarily responsible for the overall ailment of the company at hand.

The fact that these companies were losing more money at a faster rate than some of the others in the industry indicated that there was something wrong with their management. Apparently only the Depression could disclose inherent difficulties. Had the Depression not come along, these firms could have gone on without even noticing that their efficiency was slipping.

The consulting firm Bentley, Bentley, and Schwarz stated that a large percentage of losses resulted from wasteful utilization of plant facilities. They contended that capital which was not used at all, or was used inefficiently, added to costs in the same manner as if it were fully used. When a plant failed to turn out as large a volume as it was equipped to produce, it was wasting capital. This was overcapacity. The managements of these companies, however, stated that the plant capacities were all right, and that in normal times such a situation would not be considered one of overcapacity. Some of the vice-presidents and managers insisted that since government figures indicated that 20% of the nation's blast furnace capacity was unused and that 70% of the steel plants throughout the nation stood idle, in addition to the 50% of the copper smelters which were also out of business, the predicament in which they found themselves was a typical business problem. It was due not to inefficiency, but to the Depression. The company leaders contended that other companies were in a sense plain lucky that they were in a financially liquid position; their liquidity saved them from disaster. Contrary to these assertions, Bentley, Bentley, and Schwarz made the following list of observations, which they presented to the board of directors at its second meeting and which tended to contradict assertions made by the various plant managers.

Although the sister companies in question were in the various steelmaking, blast furnace, and finishing mill branches of the steel industry and were often located in the same vicinity, they did not constitute a homogeneous group. The biggest source of loss seemed to result from the necessity to cool off the hot metal and take it to another sister company where it had to be reheated. This meant not only an excessive fuel bill, but also double handling of pig iron or ingots in several plants. In other words, before the mill could handle them, ingots had to be a certain temperature in order to make wire, beam, sheet metal, or other metal products. Furthermore, because quantities produced in the furnace were small, blast furnace gas in the various smelters went to waste; not to speak of the 15 to 20% of metal which seemed to "evaporate" with the gas. These wastes had to be avoided in the future.

Before consolidation, it was all right to cater to different consumer wishes, but it was foolish to produce small quantities now. In checking the records of two Pittsburgh plants, the discovery was made that the same gage and type of sheet was made during June of the same year in two different companies belonging to Amalgamated. One mill could evidently have handled both smelting and finishing without substantially greater costs. Thus, with one fuel bill, one transportation, and merely a few extra hours of labor, almost twice as much could have been produced without overtaxing the capacity of either the smelter or the finishing mill. Although these were only two recent examples, the investigation indicated that many wastes of this kind were still in existence.

The spokesman of the consulting firm stated that they also checked the steel products turned out in the various sister plants (formerly independent companies). The results recorded turned out to be similar. They found almost identical sizes, types, and grades of steel on the production schedules of different plants. It was apparent that standardization was necessary here, in addition to the need for specialization among plants, to bring about greater production efficiency.

The consultants contended that production density and output from plant and equipment were too low. Furthermore, there was a complete lack of flexibility of plant production facilities and no provision existed for future low-cost expansion of plant facilities. Since a large part of facilities were then unused, this inflexibility was not readily apparent. If one considered iron and steel production as a cycle, it was apparent that the combine's iron- and steelmaking process took an excessively long time in comparison with companies which carried out the whole steelmaking process under one roof.

It appeared to the consultants that there were too many delays, temporary storages, back-and-forth transportations, coolings off and reheatings, and the like. Obviously, this situation caused costs to rise.

Since formerly independent companies were now integrated under one jurisdiction, it was possible to rearrange plant facilities in a manner which would lead to effective production. This apparently required new layout arrangements. When these reconstructions were taken care of, production planning and control might be greatly facilitated. Obviously, the new situation meant that previously satisfactory plant sites, plant locations, and company facilities were now out of balance as far as the company as a whole was concerned. Unless corrected, the present plant layout of member plants would cause steady losses in the future. The accessibility to railroad sidings or streets from one sister plant to another was usually in disharmony. Feeder plants were illogically located with reference to finishing mills. While shipping and receiving departments were so arranged that they suited the purposes of independent companies, from the point of view of Amalgamated Iron and Steel, Inc. they were poorly located.

Observations indicated that existing production methods in the various companies were inefficient in several plants. This was claimed to be so not merely because operations were improperly performed, but primarily because some operations performed were unnecessary. The need for combining various related processes as well as individual operations was apparent. By the same token, some production processes should have been split among two or more plants, or, at least, they should have been divided into two independently functioning production processes within the confines of a given plant.

Some of the production facilities in the individual plants were obsolete, and the production processes were consequently outmoded. These plants should have been shut down and the work load transferred to more modern plants. The consultants also indicated that in general there was a poor combination of product layout and process layout in many of the member plants.

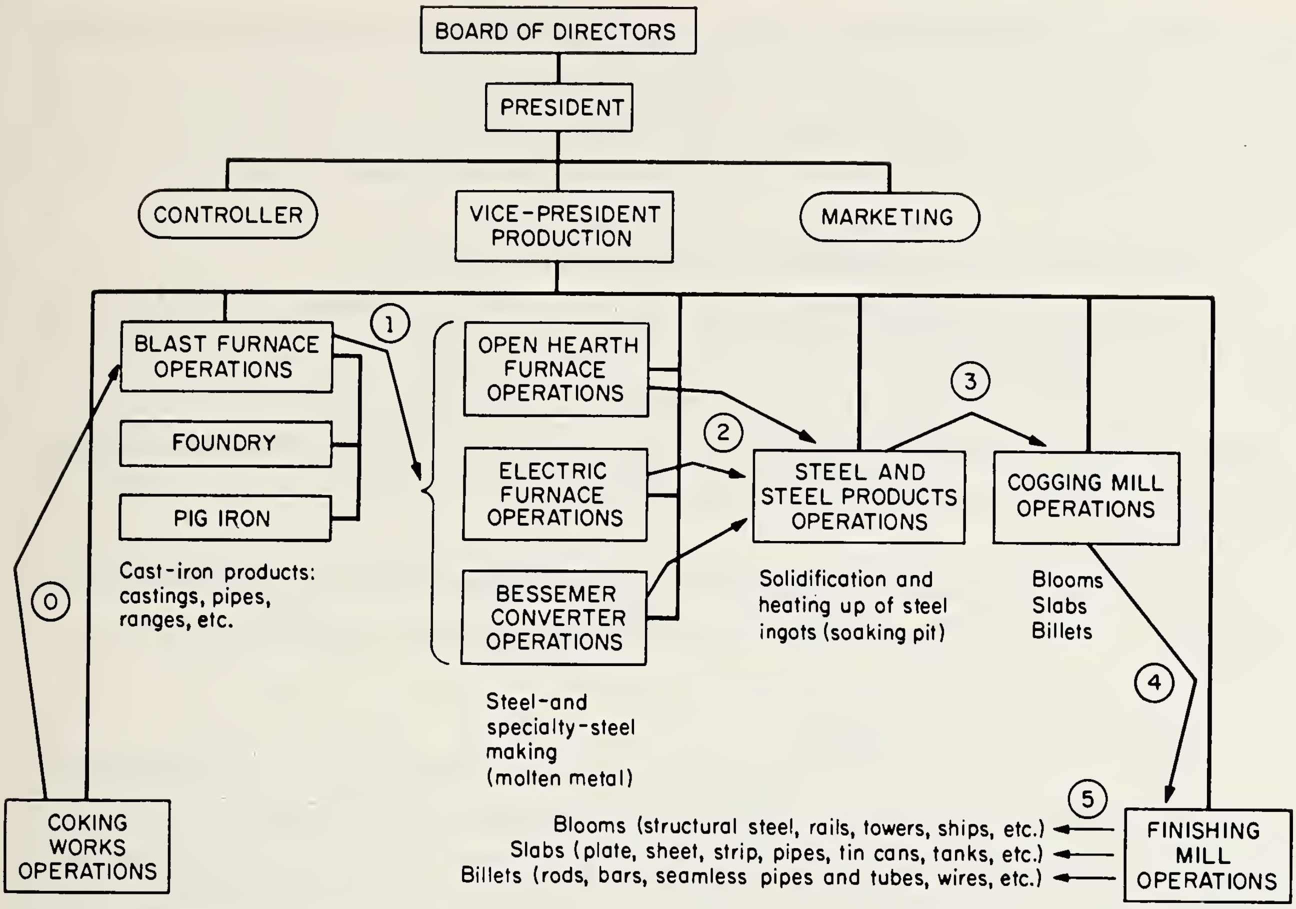
Ordinarily, plant facilities should be arranged in such a manner that production flows through the plant smoothly, even though the production in some stages of the iron and steel industry is intermittent as opposed to the rolling mill phase, for instance, which is almost a continuous production process. Although the steel industry seldom makes standard products, this fact should not hinder highly efficient plant layout arrangements.

Management of the larger plants within Amalgamated contended that material handling was most costly for them. Long hauls, backtrackings, awkward crisscrossings, and bottlenecks in material handling were common.

Even though idle capacity had indeed existed, in many plants equipment was overused and undermaintained. It was apparent that some of the financial losses from shutdowns were caused by lack of standby equipment or alternative methods for use in case of a breakdown, rather than because of lack of business. Finally, the consultants reported that a general unbalance existed between the location and technical integration of the various processes from blast furnace work to the finishing stages. Obviously, an integration would allow correction of the deficient distribution of plant capacities in the various stages of iron and steel production. It was possible, within the confines of a big concern, to adjust iron smelting to steel production, steel production to rolling mill capacity, alloying to smelting as well as rolling capacity, etc. In this way undercapacities could be remedied at their sources and overcapacities could be eliminated.

According to the consultant's report, efficiency could be achieved through proper rearrangement of the plants and through carefully preplanned intra- and interplant specialization. Furthermore, great savings could be achieved by reorganization of the heating and power systems. Particular reference is made to coal carbonization. The consolidation would allow a greater degree of by-product utilization than had been practiced in the past. Dry distillation of coal (making coke out of coal to be used in the blast furnaces) could be centralized rather than having coke ovens in operation near each blast furnace facility. Although transport costs would rise somewhat, the by-product utilization would more than compensate for the added transportation costs for coke. Since the amount of gas which is formed during the breakdown of the coal was considered too small to warrant recovery for the purpose of by-product utilization, in the past the gas had gone out with the smoke. As an alternative, pipelines might be established to carry the gas formed in each coking plant to a new chemical plant to be established. Either method would lead to added revenues as a result of the substantial value of the many useful chemicals which are vaporized by the high temperature of the coking oven (about 1900 to 2000 F).

The present organization structure of the combine, which, as shown in the accompanying chart, incorporates almost every phase of the iron- and steelmaking business, should not be disturbed, the consultant's report empha-


BOARD OF DIRECTORS
PRESIDENT
CONTROLLER
VICE-PRESIDENT PRODUCTION
MARKETING
BLAST FURNACE OPERATIONS
FOUNDRY
PIG IRON
Cast-iron products: castings, pipes, ranges, etc.
①
OPEN HEARTH FURNACE OPERATIONS
ELECTRIC FURNACE OPERATIONS
BESSEMER CONVERTER OPERATIONS
Steel-and specialty-steel making (molten metal)
②
STEEL AND STEEL PRODUCTS OPERATIONS
Solidification and heating up of steel ingots (soaking pit)
③
COGGING MILL OPERATIONS
Blooms
Slabs
Billets
④
⓪
COKING WORKS OPERATIONS
⑤
Blooms (structural steel, rails, towers, ships, etc.)
Slabs (plate, sheet, strip, pipes, tin cans, tanks, etc.)
Billets (rods, bars, seamless pipes and tubes, wires, etc.)
FINISHING MILL OPERATIONS

Organizational chart for Amalgamated Iron and Steel, Inc. (The arrows, designated 0-1-2-3-4-5, illustrate interrelatedness of different phases of iron and steel making. The finished product of one plant is the raw material of the other plant.)

sized. Bentley, Bentley, and Schwarz merely suggested that Amalgamated Iron and Steel, Inc. make every effort to realize the benefits and efficiencies of central corporate coordination. Each and every management and operation of the various member firms should retain their independence and operate on a decentralized basis, but at the same time the company should harness the benefits of the consolidation better than so far had been the case.

If several plants were engaged in the production of identical items, orders should, in the same spirit as suggested above, be channeled through a central production control department in order that each enterprise be equally loaded with work, unless earnings-wise it would pay to run a more efficient plant at capacity, while another was idled.

Questions

1. What characterized the individual iron and steel firms from the point of view of production?

2. In what respect does the production of iron and steel differ from other production enterprises?

3. Do you agree with the consultants' observations and conclusions?

4. What benefits, if any, will the steel companies derive from the fact that so many varied activities are amassed under one corporation? (See chart listing the various operating segments and their relationships to one another.)

5. What benefits will the steel companies lose as a result of the consolidation?

6. List in an order of your own choice the problems which must be solved in order to put production in the various companies on a profitable basis.

7. What faces the combine in the immediate future?

8. Separate the production problem per se from financial, organizational, and other considerations.

9. List the advantages and the disadvantages caused by the fact that various enterprises which produce a great many different products, but belong to the same company, are directed and controlled by the same top management.

10. Do you agree or disagree with the organizational arrangements according to which each company has retained its relative independence?

2-2. English Clothing, Inc.

Originally, English Clothing, Inc. was a selling agent for several textile mills throughout the country. The agency represented primarily British and Canadian textile interests operating in the United States. To alleviate the dollar shortage back in 1945 to 1950, the British authorities facilitated the financing of the activities of English Clothing, Inc. The company widened its scope of operations and acquired a few smaller mills engaged in various phases of textile production. In 1953, however, the company became a fully American-owned corporation. By that time it had integrated vertically and horizontally with many small and large textile mills throughout the United States. At that time the assets of the company were measured in millions of dollars.

According to government sources, the expansion of English Clothing, Inc. was so quick and far-reaching that an investigation was in order. The president of the company was summoned to the capitol, where the Senate's Subcommittee on Anti-trust and Monopoly (Senate Judiciary Committee) made preliminary investigations to determine whether a monopoly was being created and whether or not an indictment against the corporation was warranted.

To various questions, the chief executive of the combine explained that in view of worldwide competition, textile profitability was such a complicated matter that the members of the subcommittee should be intimately acquainted with the plight of the textile industry as a whole, particularly because of a pending bill to facilitate modernization through added depreciation allowances on textile machinery. While it was admittedly true that the company was by then large enough to have some impact upon textile prices, foreign competition would have made any such attempt unsuccessful. Japanese and British textile mills, and recent Indian textile development would have prevented noticeable effect on textile prices. As a matter of fact, the only reason why English Clothing, Inc. was able to make profits in face of cutthroat competition was that it succeeded in cutting operating costs to a level which made the operations of the corporation profitable. In view of the gyrations in raw cotton prices, which tend to regulate to a great extent the prices of cotton yarn, gray goods, finished cloth, and fabricated articles for clothing and household goods, it was incredible that any educated group should speak about monopoly in the textile industry as a whole. The same was true of woolen goods. No company could control the fluctuations of the world-market prices of wool or the resulting price of woolen goods. English Clothing, Inc. could control the labor costs to some extent because of its efficient operations which are the result of its size. But, so far as he knew, it was not a crime in this country to be efficient! In the textile business there was a buyer's market, which generally prevented anybody from controlling prices. Furthermore, the textile industry consisted of so many small, medium, and large producers that no one company could influence prices in the sense that monopolistic price determination could be claimed.

Even though English Clothing, Inc. showed a total profit much higher in percentage than the national average, if the committee had checked the books of the individually operated plants, it would have discovered that many of the spinning and weaving mills operated at a loss. In other words, these companies could not have existed—and would not have offered jobs to textile workers—if they had not been part of a combine which could offset losses by gains in the later stages of production.

The president of English Clothing, Inc. went on to claim that their profits might be high in comparison with profits of other textile enterprises because they were willing to scrap and replace old and outdated equipment with new equipment even more efficient than that utilized by Japanese mills, even though the tax laws then made no provision for faster depreciation allowances.[4] They increased their share of the market not by operating three shifts, but by raising the productivity of the workers through technological improvements. They had done something about raising the low margin of profit, and now, he complained, they were accused of being monopolistic in their operations. They were one of the few companies which could grant wage increases to members of the Textile Workers Union of America (AFL-CIO) in face of declining profit margins and employment and increased competition.

Their horizontal type of integration, he said, was directed primarily to specialization, not to cutting out competition. As selling agents they were in contact with various firms which could not sell and make profits despite the best efforts of English Clothing, Inc. to secure them profitable prices for their products. Unless these firms specialized in the production of a limited number of items, rather than made everything, profitability was nearly impossible. English Clothing, Inc. merely advised them to join their forces to secure the efficiencies of large-scale production. That subsequently English Clothing, Inc. acquired control over the producers of yarn goods and gray goods and made them specialize was in the interest of expediency, not to curb competition. They transplanted equipment from one plant to another and exchanged know-how among plants. By doing so, they created a small profit margin for these companies; but some of the companies were still producing at a loss even if depreciation costs were not taken into consideration. By combining the companies, proper cost accounting procedure reduced the profits of some companies or plants. This meant that the English Clothing, Inc. could prevent excess profit in one company while in other companies losses were suffered. By thus saving on undue taxes, English Clothing, Inc. was made a relatively healthy organization.

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[4] Recent legislation for faster depreciation allowances in textile machinery was at the time of this hearing not yet enacted.

However, overall profitability was still less than 3% after taxes. To raise the overall profit margin, the company attempted to gain some additional profits by eliminating the middlemen. When they subsequently integrated with several finishing plants, they gave them a cheap source of supply and, in turn, shared in their profits. When they acquired Sanborn & Brothers Manufacturing Company, Inc., they tried to subdivide the profits among themselves and eliminate the costs involved in the buying and selling of textile products. "Why the virtue of cost reduction and economy is considered a monopolistic practice is beyond me," concluded the president.

The above paragraphs are paraphrased from the various statements made by the president of English Clothing, Inc. before the subcommittee looking into alleged monopolistic practices as far as the company was concerned. Although the case was dropped, it was enlightening to most members of the Senate committee that despite powerful attempts to be efficient, some industrial enterprises associated with commodities like cotton, wool, and natural fibers cannot control their costs and prices as easily as other producers not related to an agricultural industry.

Questions. The English Clothing, Inc. case involves the student not so much in the intricacies of production per se as in the interrelatedness of various phases of textile production. Spinning, which consists of innumerable productive steps; weaving, which also consists of many different operations; finishing, including bleaching, dyeing, finishing, printing, which are also divided into different steps; and manufacturing of clothing are closely related as far as profitability is concerned. While it is relatively easier to control costs and prices in the manufacturing and finishing stages, it appears difficult to control them at the lower stages of production. So, an integration might make the production profitable despite the price fluctuation of the raw materials.

1. If English Clothing, Inc. was not an integrated textile mill (that is, raw

material to garment), could it have cut its costs of production by better methods, better equipment, and better raw materials?

2. Is it not true that efficiency depends on how well management is able to arrange the factors of production? Why can a small- or even a large-scale spinning mill or weaving plant not arrange the means of production in such a manner that profit results?

3. How is it that an American industrial enterprise cannot very well compete with foreign producers in the field of textile production?

4. Point out the reasons preventing the textile industry from spinning, weaving, finishing, and manufacturing on an equally profitable basis. Base your answer on the discussion between the senators and the president of English Clothing, Inc.

5. List the possible causes for the relative inefficiency of the majority of enterprises in the textile industry.

6. Give solutions to the problems listed under Question 5 as if you were the president of a spinning mill.

7. Compare the textile industry with the cigarette industry. Remember that both rely on agricultural products as the raw material.

2-3. FERRO CORPORATION

Ferro Corporation operates a large number of plants throughout the United States and abroad. Originally a porcelain enamel frit producer, Ferro Corporation gradually extended its operations to related or otherwise compatible fields of industrial endeavor. Currently the company produces in eight different strategically located divisions in the United States and in nine foreign subsidiaries, in addition to being associated with four companies operating in Chile, France, Japan, and Spain. Some Ferro production is under a licensing arrangement, the most important being fiberglass which is produced in Nashville and is turned into more finished forms in California, Florida, and Holland.

The subsidiary companies operate independently, but the financial statements, particularly the earnings, are consolidated with the statement kept at the Cleveland home office. The main obligation of plant management in the United States or abroad is a high degree of profitability.

The most important Ferro products are porcelain enamel frit and related binding and coloring agents, glaze frit, chemicals, refractory specialties, processing equipment, and engineering services related to the above products. Frit—the substance which is used to make porcelain enamel and ceramic glaze—is the main product. Frit is still the biggest item sold abroad (70% of foreign sales), but on the home front it is closely rivaled by the eight-year-old fiberglass division. In 1959 frit brought in 30% of the dollar value of domestic sales compared to 15% which fiberglass added to Ferro's sales.

Frit is the essential element of the glass coating which, when mixed with colorants and other binding agents, is used to put a thin beautifying and sanitary coat on various metals as well as on tile, dinnerware, and many other items. The enamel can be used for many elements in home construction, such as exterior curtain walls, interior-wall surfaces, and doors. The general acceptance of the enamel-frit type product can be illustrated by the fact that it is hard to imagine refrigerators, washing machines, pots and pans, and thousands of other household and industrial items without an easily washable rust-protective enamel coating.

While Ferro's best fiberglass customers are the boat builders, the chemical division's customers are the plastic manufacturers who use Ferro products to stabilize vinyls, polyethylene, and polypropylene.

Not long ago the original name, Ferro Enameling Company, was changed to reflect the fact that the company's operations are no longer confined to enamel frit. The branching out in different directions was related to declining profitability—due to a declining sales volume—in the frit business. With the passage of years the United States markets for many appliances are increasingly dependent on replacement sales rather than dynamically growing new businesses. As the company noticed the approaching saturation point, it was necessary to look elsewhere, where growing markets would assure sales and company profitability. Furthermore, company earnings were much too dependent on the appliance industry and on housing, with which bathtub, sink, stove, and similar types of business are associated. Depressed conditions in these industries automatically caused low earnings at Ferro Corporation.

The branching-out process does not imply that Ferro is not doing everything in its power to widen the gradually saturating market. As a matter of fact, serious attempts are made to increase the versatility and added usefulness of frit. Engineers are working on a one-coat enameling method capable of replacing the conventional ground coat with an electroless nickel deposit. The ultimate goal is to lower the firing temperature to 1250° F, which would open new markets and would make frit usable on lighter-gage steel plates. Furthermore, Ferro does even more to assure a market for its frit. It not only is the major builder of continuous enameling furnaces and ceramic kilns for appliance makers and other enamel users but also offers complete engineering services from specialized design to personnel training.

Despite an intensive effort to widen the market, the domestic attempts had to be supplemented to capture untapped foreign markets. The logical place was Europe which, according to the company's board chairman, "is like the United States was in the late thirties following the Depression. There's a tremendous market for all sorts of appliances. For instance they are just coming to adopt refrigerators as a standard household appliance, whereas this country is 93% saturated. At present, one-third of total sales volume comes from foreign markets. Despite its relatively small volume in comparison with domestic sales, more than half of consolidated earnings come from these foreign investments."

The geographical dispersion and entrance into other fields steadied company earning power by making the company less sensitive to adverse economic conditions. It is not likely that all areas and fields served by Ferro will be concurrently depressed, so gains in one operational area can offset setbacks associated with some of the more cyclical parts of the economy.

In recent economic developments abroad certain dangers appeared on the horizon. The European Common Market and currently developing common markets in other parts of the world seem to prevent American firms from selling abroad to such an extent as has been customary in the past. Therefore, to protect the market which is available, it is essential to open up new plants abroad. This requires added capital investment.

Since other world markets have been invaded by the East Block countries and in view of the regressing domestic markets, at least as far as frit is concerned, it is essential to make sizeable investments in plant facilities in other areas. The acquisition of Vitro Corporation of America rounded out a complete line by adding glass colors. Ferro is increasingly interested in plastics, where it already holds a strong position. Nearly half of Ferro's 1960 appropriation was earmarked for fiberglass-plant expansion, and Ferro had still more irons in the fire outside its original frit and related fields.

In view of the necessity to expand into other fields, it is of tremendous importance that company profitability is maintained. Yet despite sales being up in mid-1960 by 4%, earnings were down 3%. Although the generally lower profit margins have caused some difficulties, falling profitability can also be attributed to the recent lag of appliance sales.

Growing competition and lower profit margins necessitate larger target sales, namely, $67,000,000, to match the 1959 earnings, which were achieved with a $63,900,000 sales volume.

Expansion, which is an essential element in Ferro Corporation's profitability, encounters difficulties because the necessary funds are not readily available. As long as the company succeeds in maintaining a profit margin adequate to attract new investors, expansion is within the bounds of possibility. But in face of current difficulties it is difficult to maintain a 5½% profit margin and to enhance it in the future. If the return on investment were to be 6 or 7%, new acquisitions could be achieved through stock exchange—which is a sort of barter in the financing business. In the past the company financed its expansion program largely from convertible debentures. The arrangement seems to be satisfactory so far as the finances go; but when creditors (bondholders) choose to convert their debentures into stock, the number of shares outstanding rises correspondingly and places a pressure on the profit earmarked for distribution among the stockholders. This simply means that there is a built-in handicap to profitability.

As long as relative stability and relatively high profitability in operations are achieved, stock market prices will reflect this. It is therefore in the interest of the company to make certain that the stock market offers a high price for the corporation's stock. Rising stock values would make company debenture bonds attractive to those who speculate in converting them into stock as the proper occasion arises. Ferro Corporation's 3⅝% debentures are convertible into common shares at $37.24 per share and are redeemable at the option of the company in whole or in part at 102% of the principal amount thereof on or before July 1, 1963, and at a decreasing price thereafter. According to the latest figures, about half of the company's debentures have been converted (out of a total indebtness of $4,979,000 about $2,730,000 remain) and full conversion would bring total Ferro common shares up to 886,000. At the end of 1962, there were only 803,000 shares outstanding. The effect of full conversion would have been to reduce earnings per share quite substantially, thereby endangering the 5% or higher minimum profitability considered essential to attract new funds.

The company's common stock has a par value of $1 per share. Authorized shares amount to 1,000,000; and of that number 748,787 shares were issued in 1959. The number of issued shares has since increased to 803,000. At the time this is being written, Ferro stock trades on the New York Stock Exchange at between $68 and $50.

In view of the preceding facts one problem, namely, the difficulty of sustaining high-level profitability, must be solved. This appears to be possible through branching out into other fields on both the American and foreign markets. The achievable profit margin is, however, greater on foreign than on domestic markets. By selecting choice locations abroad, Ferro Corporation hopes to assure its competitive ability even in those markets where the foreign seller would ordinarily have a comparative disadvantage. Despite difficulties with financing new plants here and abroad, the corporation is committed to such a course of action by the various circumstances indicated above as well as by the European Common Market. Through its active participation in the latter, Ferro takes advantage of lower material and labor costs, eliminates a large part of transport costs that are ordinarily a handicap to foreign sales, and, above all, bypasses tariff regulations and exchange rate difficulties.

Questions. The case of the Ferro Corporation indicates several important points; one is that a good profit is not only a desirable end but a necessity for some corporations. As long as the company can maintain profitable operations in the various plants, it will also be able to borrow money or sell securities necessary to finance expansion. Expansion is necessary because on the one hand the firm is too sensitive to economic fluctuations and on the other the field in which it operates (and is committed) is a decreasing rather than growing one. Hence, expansion and profitability are vital to the Ferro Corporation. It is a never-ending struggle, as far as company management is concerned, to maintain a financial return adequate to attract either the investor or the creditor.

Financing through debentures which are convertible at a predetermined price into stock is another element which keeps company management on its toes. A debenture is a glorified IOU note and is backed by reputation rather than real estate or other tangible property. To make it more attractive, the company offers the creditor the privilege of converting his bond into a specified number of shares of stock at a predetermined price. As far as the creditor is concerned, the earnings of the company are far more important than is the type of security provided by a mortgage. If the good earnings of the company drive up the market price of its stock, the bondholder can convert his debenture into stock and sell it on the open market—with a windfall profit.

Apparently, it is easier to sell to the public through debenture convertibility than through direct offering of shares of stock on the open market. This kind of financing puts an extraordinary pressure on the management of each individual plant. Each plant must be a profit center, yet the corporation as a whole is concerned with overall profitability. Because the overall profitability determines further success in the field and achievements of company objectives, namely, steady profits despite the cyclical nature of the productive activity in which it is engaged, the company finds itself in trouble as soon as profits are lower than a desirable minimum.

1. List the symptoms which indicate that the company has a problem.
2. List the causes for the above symptoms.
3. Criticize the company's policies and actions to eliminate the causes for the alleged problems.
4. If you were a consultant to the company, what would you suggest it should do to meet its problems? It is essential to keep the financing difficulties and the nature of production in mind before you make your suggestions. The suggestions you offer must be feasible rather than hypothetical.
5. Contrast the reasons for industrial combinations in Amalgamated Iron and Steel, Inc.; English Clothing, Inc.; and the Ferro Corporation.
6. Do you agree with the company's policy of expansion in foreign countries? Give reasons for your answer.
7. In recent years the properties of American companies operating abroad have often been the object of expropriation by changing governments (Cuba, Iran, Egypt, and Brazil). In view of this kind of development, do you agree with a company policy of overseas investment?

chapter 3

Organizing for Production

With skill and the necessary capital equipment an entrepreneur coming to the New World at the turn of the eighteenth century could do well.

As an illustration of how development might be made let us take an imaginary case of a tailor. Despite considerable application he might well have found himself unable to meet demand. Tailors were scarce and profits in tailoring were assured. But to increase these profits, he would have to increase his output; and without help this was difficult. Because of the tight labor market as far as skilled tailors were concerned, he could not hire help. After exhausting all other ways and means, the tailor must have arrived at the conclusion that his only answer was to hire unskilled labor. This unskilled labor could, however, be utilized only after exhaustive study to make tailoring easy and by breaking tailoring down into simple repetitive operations. At this point, when he began to think out and plan the work of others, the tailor began his managerial activity.

His first concern was the job itself; tailoring had to be broken down into relatively simple tasks. His second problem was the job in relation to the prospective employee. He had to determine the kind of work each worker might be capable of performing without possessing tailoring skill.

This activity could be considered as planning the production process. Every detail had to be determined, and work assignments had to be made. Our tailor was engaged in planning. Ordinarily, the first phase of planning deals primarily with the physical aspects of the job (manufacturing processes, production volume, performance time, and equipment utilization), the second phase with the adaptation of the job to the varying skills and abilities of prospective employees.

THE PLANNING FUNCTION

The example of the immigrant tailor indicates that the first and most important managerial function is planning. It is the basis for effective decisions. Planning determines avenues for accomplishing production goals effectively; it states in advance what ought to be done.

Plans should preferably, but not necessarily, be written. It is better to jot down possible courses of action than to manipulate the various possibilities in one's mind. Particularly where complex items with complicated processes are produced, planning must be on paper. Of course, plans are often neither on paper nor made as the occasion arises in the heads of executives; they may merely be embodied in unwritten procedures originating in past experiences.

The extraordinary importance of planning was recognized by the early writers on management. Fayol remarked, "If foresight is not the whole of management, at least it is an essential part of it. To foresee means both to assess the future and make provisions for it; that is, forecasting is itself already action.[1] In precipitating future happenings, it is essential to consider all factors which might affect production as a whole. Since production problems are complex, the interaction of various related factors deserve careful attention.

The factors to be considered are often technical in nature; but since the labor factor means people, the influence of the human element cannot be neglected. Hence, the planning process centers mainly around the economical utilization of materials, equipment, and workers. Whether this is accomplished will be manifest in effective operations. It is the *plan* which, in a sense, guarantees optimum utilization of the production factors and concomitant low-cost operations.

THE CONTROL FUNCTION

One should not think of a plan merely in terms of a plan of action. It can also be considered as a means of control and a criterion of judgment. After production is accomplished, the plan can be used to determine the extent to which deviation from the plan has occurred. This comparison between plan and action, particularly when expressed in some sort of a common denominator such as cost, can become an excellent basis of measuring effectiveness. For this reason, it is essential that planning should be based not on conjectures, but preponderantly on facts. These facts must of course come from carefully collected and tested data rather than from opinions or other unreliable sources. Although data used in planning are merely means by which plans are established, without a uniform body of facts planning would be difficult and evaluation handicapped.

Plans based on facts leave little room for error. Even so, plans are seldom perfect; for predetermined action is rarely foolproof. Since the plan is made in advance of performance, it is bound to be based upon certain assumptions. If the circumstances or the factors underlying the plan have changed, it is apparent that the plan must undergo corresponding changes. While even variable relationships follow certain predictable paths, the planner miscalculates if his assumptions regarding machine breakdowns, strikes, employee disregard of production standards, etc. do not hold true. Since plans always deal with both known and unknown factors, the accuracy of plans tends to depend on the quality of the planner's foresight.

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[1] Henry Fayol, "Administration industrielle génèrale," translation from the French in Luther Gulick and L. Urwick (eds.), *Papers on the Science of Administration* (New York: Columbia University Press, 1937).

WHAT SHOULD BE PLANNED AND CONTROLLED

Taylor,[2] whose ideas about scientific management were among the first to place emphasis on planning, stated that what should be done and how work must be performed to gain the best results must be determined at the outset. Furthermore, planning should determine the route through which the work must progress toward its completion. Plans should state when work should be started and finished as well as how much it should cost. If action is based on carefully determined plans, both productivity of labor and a better flow of production can be achieved.

It is apparent that, basically, planning is a systematic search for prospective problems on the one hand and their solutions on the other. Planning deals with what is to be done and how, where, and at what time it is to be done. *Who* is left out purposely, not because it does not constitute a part of the planning process, but because the planning process in industry is often divided between two groups of people. The physical aspects of production are usually planned by staff departments; their work is subsequently related to labor and performance by line personnel. Line personnel are authorized to make things happen and are responsible and accountable for actions of others. Staff departments are made up of employees, usually in management capacity, whose job is to help out line personnel.

Although who should do the work is an important aspect of planning, it is so closely related to action that it is usually considered in the light of action rather than planning. Thus, even activating work has its planning aspects. Since planning and execution will be separately discussed, this phase of planning has been omitted from the general discussion.

In smaller enterprises where planning and execution are not distinctly separated, every phase of planning is bound to be performed by line people. A line-and-staff type of organization tends to develop where planning problems (meaning the physical aspects of production) are so numerous and involved that staff specialists can be fully occupied with their solution.

NATURE OF PLANNING

Since planning has a dual purpose, namely, to predetermine action and to serve as a criterion for measuring the degree of success, plans fulfill their appropriate purposes when, in addition to determining the course of action, they also state the nature and characteristics of the desired goal; allowed performance times; completion dates; and quality, quantity, or cost of production. The plan is therefore also the most effective way of exercising control over productive actions. Probably this is the reason why the department in charge of setting up production programs is frequently called the production control department rather than the production planning department.

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[2] Frederick W. Taylor, *The Principles of Scientific Management* (New York: Harper & Bros., 1911).

Unless the plan is based on true and representative facts, it is of little value as far as control and evaluation are concerned. Whether these facts are collected through time studies, systematic record keeping, statistical sampling, or other appropriate means is unimportant. No planner can set up plans regulating the flow of production unless he has at his fingertips information about performance times, machine capacities, delivery dates, etc., as well as about processing plans.

We have, so far, gained sufficient knowledge about planning to discuss how accurate these plans must be to control the intended actions. Hence, the plan 1) should be based on facts, not wishful thinking; 2) must be correct from the point of view of logic and technical and verbal clarity; and 3) must be as adjustable as the flexibility of the factors which it aims to regulate permits. The adage "rules are made to be broken, plans are made to be changed" is not a paradox.

Nevertheless, production plans must have some degree of stability. They must be stable enough to rely on but flexible enough to accommodate the changes which are bound to occur in production situations. A good plan should never become so obsolete that it has to be totally abandoned. If the core of a plan is based on fundamental principles, it may have to be overhauled, but never replaced. Exactly because time is the essence of planning, changes not foreseen at the time of inception must have due consideration later on. Flexibility must be built into plans to permit a reasonable amount of deviation from the chartered course of action without risking the breakdown of the plan itself.

Even sound plans which allow for flexibility may go astray because of the inflexibility with which they are carried out. Planning and execution are inextricably interrelated, yet there is sometimes a tendency to separate planning from practice. Particularly in such instances, coordination between planner and executor is necessary.

STAFF PLANNING FOR LINE USE

Plans deal with large as well as small problems. This implies that detail, scrutiny, and comprehensiveness are essential characteristics of production plans. Plans should regulate all pending actions, large or small. Yet details do not imply an unduly rigid course of action.

Although management today is scientific, it is far from being a science. For this reason, the plans do not have to be blindly followed unless the executor fully agrees with the plans. Thus, the planner should know that no plan should take initiative, zest, and willingness to make decisions away from its executor. The planner should keep in mind that staff work is there to facilitate the work of people in charge of operations. While at times details may add to the value of plans, unnecessary comprehensiveness and complexity may hinder rather than help those who activate them. This applies particularly to those plans ultimately directed to operating management. Background, experience, maturity, and intelligence of operating personnel seldom allow absolute precision, yet all information needed for action must be incorporated in the plan. Hence, the plan must always be in the language of its executor.

Obviously, plans developed for higher-ranking members of management must be written differently from those directed to operating personnel. The latter should spell out all steps, while the former can merely imply the obvious. Basically for this reason plans directed to foremen should be written on forms or cards and require little time to read and understand.

THE PLANNING DEPARTMENT

Planning problems in our immigrant tailor's small-scale business were relatively few and simple. He had adequate technical knowledge and know-how to solve them. In large-scale production, however, problems are proportionately more numerous and complex. Hence, the knowledge of one or two planners is just not adequate. The large-scale producer therefore employs a score or so of planners.

The *raison d'être* of a large number of planners is lack of time and knowledge on the part of line executives; planning problems are so numerous and often so complex that individuals can handle only a small portion of the total planning work. For this reason, the planning function is often divided among many specialists who tend to solve only certain types of problems; in fact, some members of the planning group are not even engaged in planning work proper, but merely collect and evaluate information necessary for planning.

Our main concern is with the department which plans the flow of production and assigns starting and finishing dates. This department is referred to as the production planning, or production control, department. While it sets up overall production plans, it is evident that it cannot function without information received from other planning departments. Therefore, the production planning department goes to other specialized planning groups when certain information is needed.

The other planning departments concern themselves primarily with technical details. They work out solutions to certain technical problems and decide the best possible course of action. The results of these departmental activities constitute in a sense *partial plans*. Since the production program is nothing but a summary of many small plans, it is the function of the production planning department to collect all partial plans and information from other planning groups and make out of them a uniform plan, that is, a production program.

The production planning department, then, has two functions: planning and coordinating. The latter refers to the activity of pulling the efforts of other departments together. It should be remembered, though, that coordination is an incidental and not a purposeful function of the production planning department. The planning group has to acquire information upon which to base its plans, and as a by-product it virtually coordinates the work of other staff departments which deal with specific planning problems. Because of this coordinative character, the production control group is frequently referred to as a coordinative staff department.

PUTTING PRODUCTION PLANS TO PRACTICE

Even though our tailor was engaged in planning, he still remained a craftsman. He became, however, a part-time manager as soon as he planned, directed, and controlled the actions of his hired hands, in addition to his physical work. When he stopped working altogether and instead devoted his time exclusively to selecting his workers, training them, and seeing to it that they were performing according to his predetermined plans, he became manager of production.

In this capacity, his primary duties can be summarized under the following topics: 1) planning, 2) organizing, 3) directing, 4) controlling, and 5) coordinating the efforts of others to accomplish the production goals with the utmost precision and efficiency.

Although more will be said about the various managerial activities, for our present purpose a brief recapitulation must suffice. We have already seen that where the planning function is not done by specially hired staff people (staff departments), it is done by line management whose ordinary job is to take charge of production. In the case of our tailor, he performed all five managerial functions. Yet the nature of planning is such that it is not essential that the supervisor (our tailor was basically a supervisor) should do it himself. The line-and-staff organization develops when the line man becomes too busy or the supervisory duties become too complex for the supervisor to perform with a sufficient degree of effectiveness.

What really happens is this: if one supervisor becomes too busy, we add another supervisor, then a third, a fourth, etc. In this situation all supervisory personnel plan and execute the work falling under their jurisdiction. If we assume that the number of supervisors grows to ten as a result of growth of the company and now an eleventh supervisor is needed, the question arises whether it would be better to add a planner to the organization rather than to hire an additional foreman.

The wise choice often would be to hire a planner who will be able to do most, if not all, the planning for every supervisor. This way the burden on the shoulders of the ten supervisors will be reduced and they can handle more subordinates than they otherwise could. If foremen supervised fifteen subordinate employees and performed all five functions of management, namely, P + O + D + C + C, addition to the number of subordinates would gradually reduce the effectiveness of each supervisor.

Let us see what would happen if we added a staff man to the organization rather than an additional foreman. Table 3-1 indicates that 10 foremen can effectively control, say, 150 employees and still perform all the other managerial duties of planning, organizing, directing, and coordinating the efforts of subordinates. If we add a staff man who can assume the production planning function, which represents roughly 50% of the work of supervision, it is conceivable that the following results will be attained:

TABLE 3-1

Foremen	Number of Employees	Managerial Duties	Supervisory Work Load, per cent
1	15	P + O + D + C + C	100
2	15	P + O + D + C + C	100
3	15	P + O + D + C + C	100
4	15	P + O + D + C + C	100
5	15	P + O + D + C + C	100
6	15	P + O + D + C + C	100
7	15	P + O + D + C + C	100
8	15	P + O + D + C + C	100
9	15	P + O + D + C + C	100
10	15	P + O + D + C + C	100
10	150	P + O + D + C + C	1000

Foremen, 5	No. employees, 150	Duties, O+D+C+C	Work load, 100%
Planner, 1		Duty, P	Work load, 100%

What we have really done is to hire a specialist who is attached to the line organization and, so to speak, works for ten foremen. As a result we get better production plans, since a well-trained and qualified central production planner can better allocate work loads to departments and can achieve a better utilization of plant facilities than each foreman, who tends to see things from his own limited perspective. From the point of view of production, with the above arrangement each supervisor can handle, say, thirty employees without being overworked and overloaded.

This method of dividing the managerial functions between planning departments and line people is the basis for the so-called line-and-staff type of organization.

In an organization where most of the planning work is done by one or several staff departments, the function of supervisory personnel tends to be reduced to putting plans into practice. But no supervisor is fully able to escape the obligation to do some degree of planning. Even in organizations of the line-and-staff type, some degree of planning is always present in supervisory work.

DUTIES OF PRODUCTION MEN

Our tailor decided to hire unskilled help because skilled tailors were not available. One could say that his inability to find other tailors to help him forced him to engage in planning. Planning was the initial step enabling him to make use of unskilled labor. Then the plan had to be put into practice. Suitable individuals had to be selected and placed in different jobs. The planning work separated tailoring as a whole into elementary operations, and now each work station had to be assigned to a workman. Someone had to be selected to perform the cutting operation, another to sew up the seam, a third to press it, and so on. This procedure had to be followed throughout the entire process of making a suit. At the time each individual operation was designed, each was of such a simple nature that unskilled individuals could quickly learn and perform the particular job. When our tailor selected the suitable man for the job, he was engaged in the second managerial activity: organizing. In its simplest form, this refers to picking the right man for a particular job.

Organizing

Matching talents with job requirements can be a painstaking activity. One does not select existing talent so much as potential ability. Thus, our tailor was not so much concerned with the individual's prevailing skill as with searching out teachable individuals. The ultimate success of production depended to a large degree on his ability to pick the suitable man.

While planning divides the work into specialized routine jobs, proper choice of the person laid the foundation of proper performance. This activity required intimate knowledge about the skills, shortcomings, personal likes and dislikes, and idiosyncrasies of subordinate employees.

Directing

After our tailor selected the right person, his managerial duty centered around directing employees in the performance of work assignments. Direction consisted of explaining the assignment and the manner of performance and subsequently letting the employee try to do the job under supervision. Direction required an abundance of common sense and a rather delicate knowledge of good human relations. There was no rule as to how our tailor should deal with his subordinates. Each person had to be treated differently. Our tailor had to learn the art of leadership. He had to learn how best to communicate with people.

Production through leadership was quite different from tailoring through one's own physical skill. It was a skill our tailor had to acquire. Whether his leadership was good or bad was apparent from the reaction of his subordinates and how well they followed his commands. It was a natural process to follow his instructions, since he was able to gain the respect of his men by virtue of his skill in the production of suits. It it likely that employees followed him willingly for other reasons too; their income and job depended on this leader-follower relationship.

Control

After a while his employees became proficient in their jobs. This was possible because their activities were confined to a limited number of steps. As soon as an overall proficiency was reached, our tailor no longer had to concentrate on direction; he could concentrate primarily on control. While direction is used here in the sense of training, control refers to seeing that everything is accomplished according to plan. It means, among other things, corrective action and steady surveillance of work to detect errors and deviations on the one hand and maintaining full utilization of employee time on the other. Occasionally it might refer to disciplinary action to force employees to conform to certain rules. While our tailor might have assigned jobs to those individuals who appeared suited to them, less desirable job assignments would frequently displease employees. When their resistance had to be overcome, control was necessary.

Control might mean also an integration of dissimilar interests within the framework of the plan. It is essential for employees to perform their respective assignments in conformity with plans, regardless of individual preferences. The function of control is to regulate behavior through the application of threat, penalty, or reward. Effective control usually achieves the objectives of the group by making its members conform to the prescribed action through intellectual persuasion. Hence, effective control implies voluntary conformity rather than coercive action.

Coordination

When our tailor separated the process of manufacturing suits into simple production steps, he was engaged in planning; he organized production when he assigned men to each step. Although diffusion of work meant many problems, it was necessary because no one, except our tailor, knew the job in its entirety. Subsequently, the parts had to be synchronized into a homogeneous whole to accomplish production objectives. But to do all this, each of the participants had to act in conformity with all the others. While controlling means disciplinary as well as corrective action to assure that single assignments are accomplished, coordination refers to a synchronization of all specialized activities. All employees had to cooperate with one another to achieve total production goals. If cooperation was lacking, the tailor had to make employees cooperate with one another. Cooperation that is forcefully achieved is called coordination.

Cooperation of participants is essential in every group action. When cooperation was not present, our tailor had to bring about unity. If he was a really good leader, he was able to develop goodwill, enthusiasm, and a feeling of belonging to his production organization. If he succeeded in developing teamwork among his subordinates, coordination was achieved through cooperation. An awareness of the relatedness of each part to the whole and the willingness to achieve it meant coordinated action.

MANAGERIAL SPECIALIZATION

To accomplish production, our tailor specialized the various activities and assigned unskilled help to simple tasks. He had to divide the job into simple hand motions because his people could not have handled complicated jobs—not enough of them had the necessary skill.

Modern production is far more complex than that. The production of complicated items such as automobiles, computers, typewriters, and chemicals requires men with extraordinary talents. But men of this kind are not available. This does not mean that we stop producing complicated items just because there is nobody who is capable of planning the production process, designing the item, planning the work flow, and supervising all phases of production. Just as the tailor applied the principle of division of labor, so we divide the managerial function into specialties. Some people specialize in some phase of planning and others in supervision; therefore, we do not need people with extraordinary managerial talents. Thus, teaming up people with different skills in various phases of management permits the production of complicated items.

By the very nature of things, the more complex the managerial activity becomes, the fewer the people who are capable of performing it. By restricting the mental effort needed in managerial areas of decision making, efficiency of managerial performance increases correspondingly. The principle of specialization is applicable equally well to management pursuits.

METHODS

Although managerial specialization can take different forms, three basic methods are available: 1) limited area of managerial authority; 2) the functional type of specialization; 3) the line-and-staff type of specialization.

By the first method, the higher-ranking managers make the important decisions and lower-ranking managers—depending on the managerial level at which they operate—make less-important decisions. The owner of an enterprise makes big decisions, his subordinate manager makes smaller ones, and his foreman makes still smaller ones. This system operates in the typical line organization, where authority originates at the top and is passed down by delegation. In this type of organization every manager does his own planning, organizes his own department, and directs and controls the activities of his subordinates.

The second type of specialization is similar to the first, since managers restrict their jurisdiction. This is done, however, in functional areas such as finance, production, and marketing. We have three line organizations in these three functional areas. Here we are interested only in production.

Specialization based on limitation of jurisdiction means that fewer people report to an individual. If for some reason or other the number of subordinates increases and the executive feels overtaxed, a new managerial level is created by reducing the number reporting to him. Functional specialization restricts not only the number of subordinates but also the nature of the activity. In other words, functional specialization, in addition to restricting the number of subordinates, takes into consideration the limits of the human span of knowledge; while the jurisdictional restriction compensates only for the span of time, which has a controlling influence on what people can accomplish.

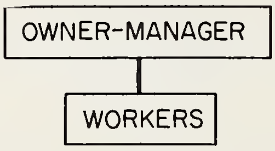

FIG. 3-1

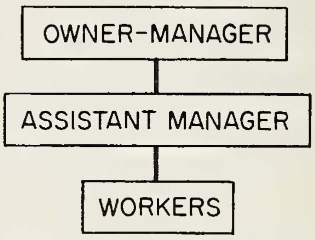

FIG. 3-2

If we start out with the immigrant tailor, his organization looks somewhat like Fig. 3-1. As his organization grew, he probably selected an assistant manager. He was himself probably in charge of everything: finance, production, sales. So was his assistant. What he did not do, his assistant did; thus, we have the chart in Fig. 3-2. As time went on, the situation changed gradually and his manager had two or three foremen, as charted in Fig. 3-3. So far, a mere restriction of the number of subordinates has taken place. Of course, with the creation of a new managerial level, the more important decisions

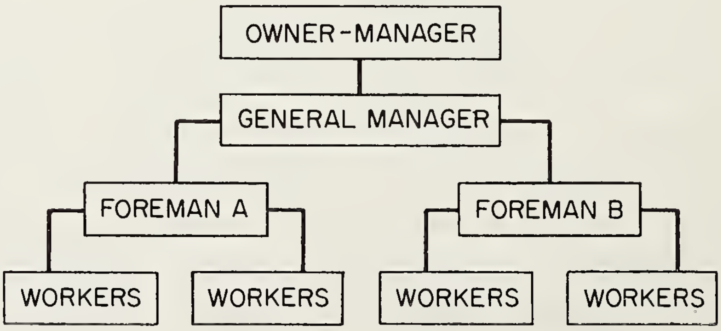

FIG. 3-3

were made by those at the higher managerial levels and the less important decisions at lower levels. This is a simple procedure. If the foreman has a production problem and feels capable of solving it, he is going to solve it. If, however, he feels that the decision requires more authority than he feels he has, he passes the issue on to his boss. If his boss should feel the same way, the problem awaiting solution keeps climbing until it reaches that particular managerial level at which someone dares to make the decision. This is the so-called exception principle according to which exceptional cases are passed on to superiors until someone feels that he has sufficient authority to act.

At this point it is conceivable that instead of adding another managerial level, as indicated in Fig. 3-4, the company would functionalize its management. Thus, there would be created an organization which, when charted, would look somewhat like Fig. 3-5. This organization restricts the area of interest of managers. Financial affairs, sales problems, and production problems are handled by different individuals. The assumption is that nobody can truly be an expert in everything. The fact is that men can concentrate their efforts on solving specific problems in restricted areas. As a rule, the decisions will be better than if they were made in all sorts of fields.

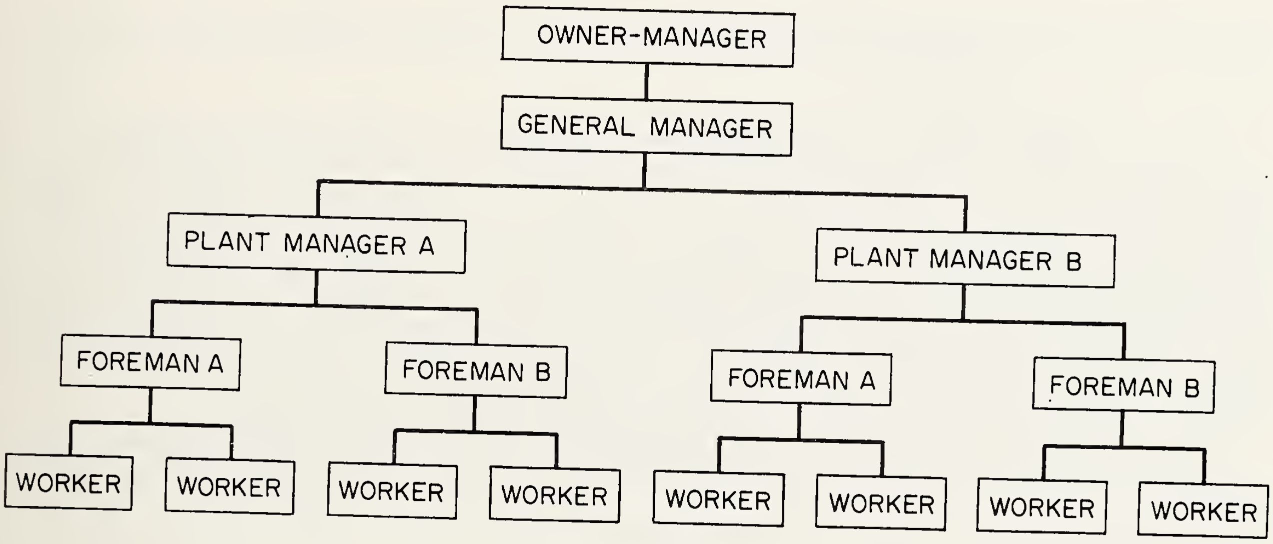

Fig. 3-4

The third situation would grow out of the functional type of organization idea. By restricting his activity, a man can easily become an expert because he is able to concentrate his effort on a specific field. Yet, it would be impossible to grant authority to everybody even on matters which are interdepartmental in character. It would be confusing if several men tried to make decisions on the same matter. Thus, for practical reasons, staff specialists are attached to the line organization, but these specialists cannot act and command as the members of the line organization can. They will work out problems for

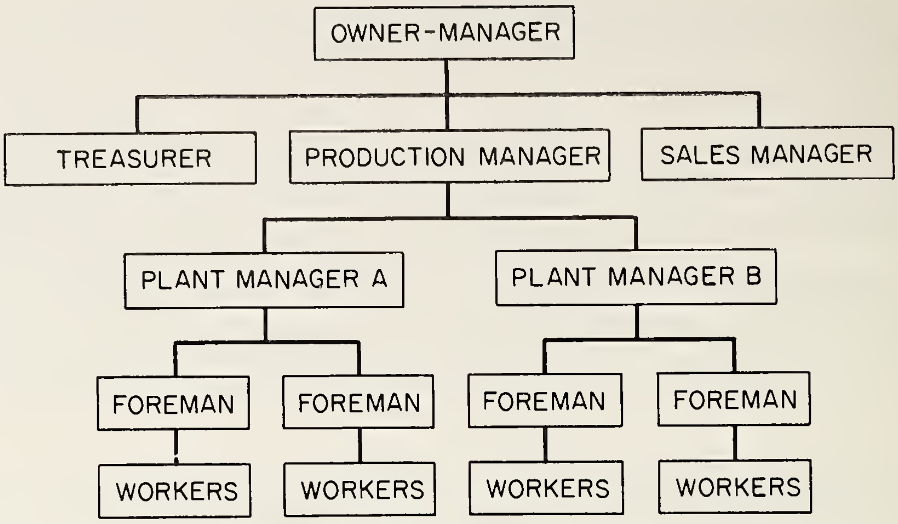

FIG. 3-5

which they are hired, pass the solution on to the line executive who needs it, and go out of the picture.

As indicated before, staff specialists usually, but not necessarily, handle problems which fall within the general area of planning. Therefore, staff specialists will, just as in the case of functional specialization among workers, restrict the area in which the executive must make independent decisions. The decision is still made by the line executive, but the problem is worked out by an expert. It is conceivable, however, that an executive may reject staff advice. Hence, staff specialists cannot force their ideas on line executives.

For the sake of illustrating the line-and-staff type of organization, let us extend the organization in certain staff areas, such as engineering, inventory control, sales forecasting, and production control. The organization will look then somewhat like Fig. 3-6. The staff departments of engineering and production planning are indicated with boxes drawn with broken lines. The other departments—boxes of solid lines—are line functions. The chart is so constructed that the advisory character of engineering and production planning is readily apparent. According to the organization chart, these two departments advise the production manager on technical or production planning problems. Actually, the engineering department works out the problems and presents the plan (design) to production. Production management ordinarily accepts the recommendations of the engineering department, but it is within the power of production management to reject them. The same is true in the production planning area.

The role of production planning departments will be illustrated in somewhat different form on the next organization chart. Special attention is paid to this department because it is the most important department as far as this subject is concerned and because every step depends on the decisions made by this particular staff group.Indeed, the efficiency of production largely

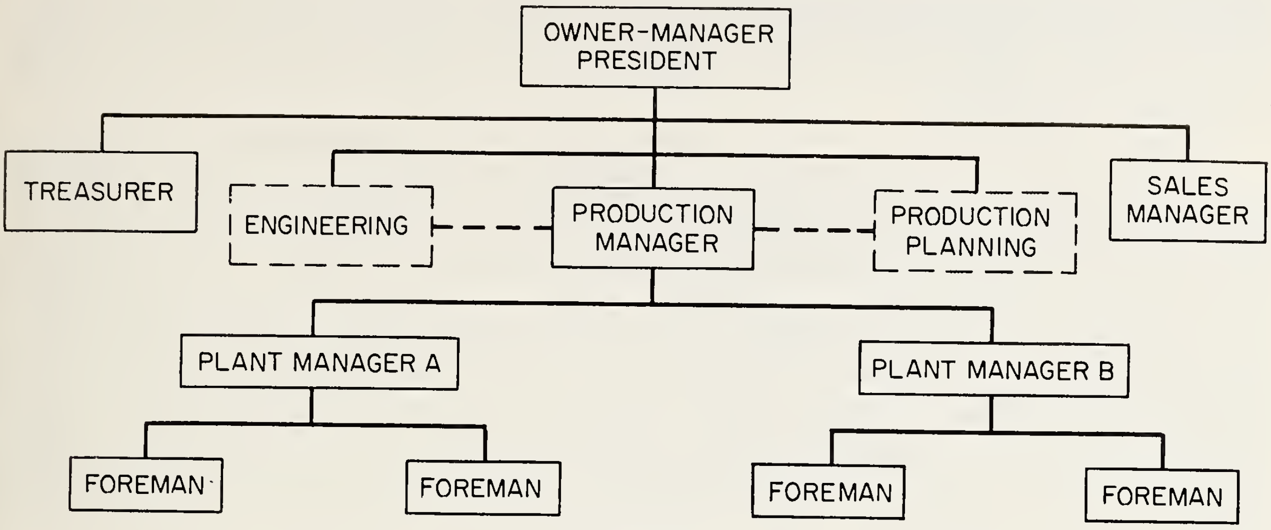

Fig. 3-6

depends on how well the production control and planning function is carried out.

Since we concentrate our interest on production, other functional departments are omitted from the chart in Fig. 3-7. While Fig. 3-7 is similar to Fig. 3-6, the student should note one difference: the level at which some of the staff departments are located. Furthermore, the coordinative nature of production control (production planning) work is illustrated. The level at which each staff department is located has something to do with the importance of the staff work and with the importance of information or plan transmittal to lower-ranking management personnel. It will be explained later that staff departments

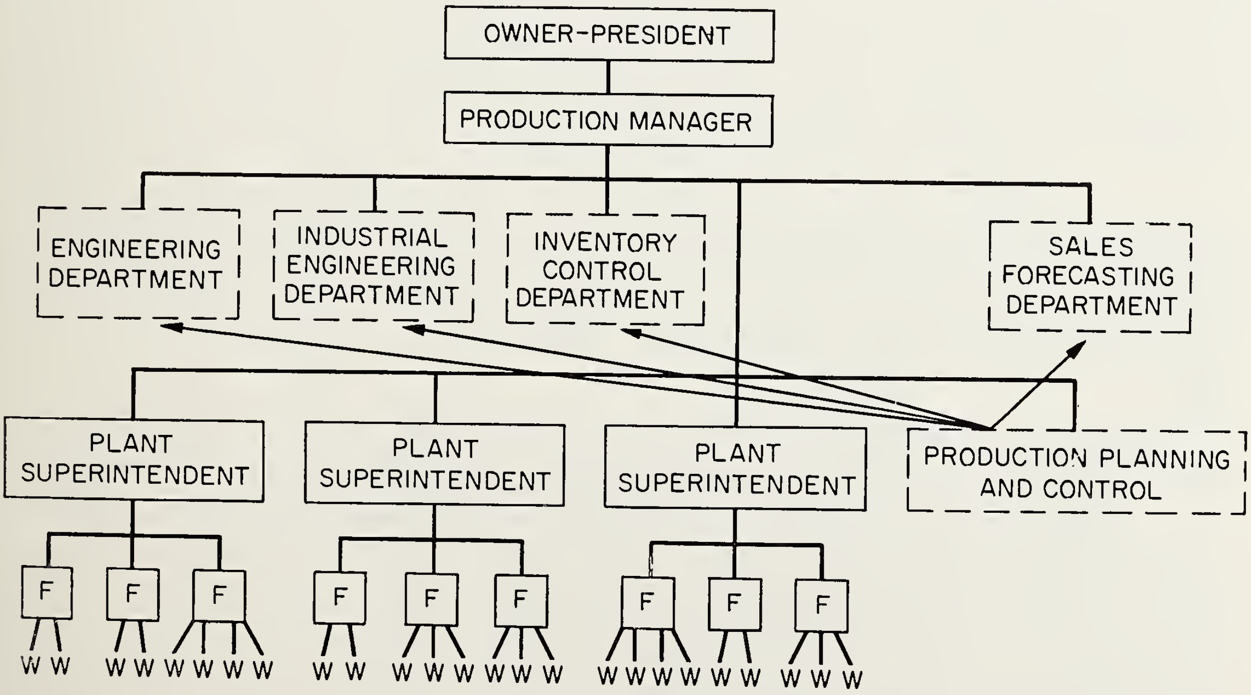
OWNER-PRESIDENT
PRODUCTION MANAGER
ENGINEERING DEPARTMENT
INDUSTRIAL ENGINEERING DEPARTMENT
INVENTORY CONTROL DEPARTMENT
SALES FORECASTING DEPARTMENT
PLANT SUPERINTENDENT
PLANT SUPERINTENDENT
PLANT SUPERINTENDENT
PRODUCTION PLANNING AND CONTROL
F
W

Fig. 3-7

operate without having authority to act, yet the level at which they are located can give staff department some implied power to act in the name of a high-ranking line authority.

While production may vary, the activity of management is always the same. Managerial activity resolves itself into five basic activities: planning, organizing, directing, controlling, and coordinating the efforts of other people. In the line-and-staff type of organization illustrated in Fig. 3-7 the planning of production activities is turned over to the production control department, planning the technical part of production is the responsibility of engineering, assuring availability of raw materials lies in the hands of the inventory control department, etc. The line-and-staff type of specialization aims at subdividing the above five intellectual skills to take advantage of the principle of specialization.

Planning lends itself to this kind of specialization because it is done on paper. Supervision (organizing, directing, controlling, and coordinating), in contrast, is a person-to-person type of relationship. While supervision requires personal presence at the place where it is carried out, planning can be done anywhere. In other words, planning is an impersonal thing. Therefore, it is easily separable from the rest of the managerial activities. The work done by engineering, industrial engineering, inventory control, and sales forecasting would also fall in the category of planning, just as production planning does.

VALUE OF STAFF SERVICE

Line-and-staff organization takes advantage of the specialization principle. It permits experts to plan things, but it does not disrupt the functioning of a typical line organization. Thus the efficiency of the line structure is maintained, yet the expert skill and knowledge of the staff men are harnessed. Obviously, staff personnel trained in planning tools and techniques in general can develop better and more precise plans than supervisors or line executives who are busy with the everyday running of things. Primarily because they are remote from the everyday happenings and because they can take a bird's-eye view of things, staff personnel can develop plans that are bound to be superior to those of line personnel. The chances are that a line member of management would do his planning on a part-time basis, while the staff man plans on a full-time basis.

Although we speak here about planning, other managerial functions can also be met by staff experts, impersonalized, and, so to speak, relegated to remote-control techniques. Thus, at times the managerial function of direction can become an impersonal thing. If so, it lends itself to staff service. Budgets, output quotas, tolerances, and so on are usually developed by staff personnel, but in their use they serve the control function. Directives are often issued by written procedures rather than verbally in order to reduce the need for personal contact between manager and employee.

However, only that part of planning, organizing, directing, controlling, and coordinating which does not necessarily require the presence of the manager can be reduced to an impersonal basis.

SPECIALIZATION AND AUTHORITY

The concepts of authority and responsibility have a great deal to do with success or failure of production. Where direct orders are given, the one who commands others to perform various productive tasks can do so only if he possesses appropriate authority. When managerial duties are separated into line and staff functions, those classified as line executives make their subordinates responsible for results. Therefore, line executives must be endowed with powers to enforce their orders; otherwise, no one can seriously think of making someone accountable. Though plans may originate in staff departments, supervision of performance is bound to be a line function.

At the operative level, command refers to assignments given to employees by their foremen. The principal responsibility involved is performance in the manner commanded. Through proper direction and control, the efforts of subordinate employees are directed toward the accomplishment of specific work projects. While at higher levels the same thing is true, commands usually take the form of administrative orders or policies.

Regardless of the level at which performance takes place, managerial tasks in respect to production require voluntary obedience from subordinates as a prerequisite to successful performance. Obedience in turn implies respect, not fear. Without such power, execution of plans cannot be carried out effectively. Authority can be defined as a power to command others. While the ultimate source of such power lies in ownership, our present interest precludes consideration of source. Line activities, as opposed to staff duties, require that their executors possess power to command. In any line activity certain work must be accomplished, and it is the task of the leader to see to it that the project is carried out. From the top executive level downward, authority is dispersed through delegation to others at a lower rank.

The delegation of authority implies that the delegator supplies, along with the power of enforcement, the criteria for measuring the successful attainment of objectives. In other words, delegation of authority must be accompanied by a desirable output expressed in terms of quality, quantity, time, and budgetary limitations. Delegated authority must, of course, carry with it a corresponding amount of responsibility. Therefore, at the time of delegation, both the degree and the extent of responsibility must be clearly understood.

While command over others requires authority, mere authorization is needed for developing plans or gathering information. Plans involve no action; they are by their very nature only preliminary steps to action. Therefore, by their nature staff activities require no authority. Care must, however, be exercised in this respect. Absence of authority should not be construed to mean that a staff specialist who is head of his own staff department has no authority over his own subordinates. Within his department he is, of course, the boss and can enforce his wishes. But outside his own department he can act only in an advisory capacity. He can render advice to those requesting it but never command performance. However, in this respect there are notable exceptions to the rule. For instance, an inspector who is on the staff cannot stop an operator except through the foreman. Nevertheless, if excessive damage may be done while he is searching for the supervisor, he may use his judgment, stop operations, and seek supervisory backing retroactively. Of course, this would be done only in emergencies.

Production plans are usually developed by staff specialists. After such plans are created they are turned over to line managers for execution. Staff specialists are neither servants to the line nor attached to the line organization. Their relationship to line members is similar to a client-attorney relationship. Staff people assume the responsibility for accomplishing a transferable type of managerial task that is usually, but not necessarily, a planning activity. They have little say, however, as far as execution of those plans is concerned. They are engaged to gather, evaluate, and supply information or give advice necessary to carry out highly technical or very specialized production activities. Once the advice has been turned over to line management, it is up to the line executive to accept, modify, or reject it.

As already noted, staff activities, by their nature, seldom if ever require authority. They are done prior to performance or are of a facilitative nature. Thus, for instance, the quality of production is the interest of both quality control, which is a staff group, and the supervisor. The latter is originally responsible for quality, because only he can build quality into the product. The staff specialist can only tell the line supervisor if he sees that quality is deteriorating. If the line supervisor disagrees with or disregards the advice and continues making inferior-quality products, he is directly responsible for the results. In other words, the foreman can overrule the inspector. The quality control man has duly performed his duty when he has told the supervisor that quality is no longer up to par. He has rendered the service required of him, and the rest is up to the supervisor. Thus, the inspector is responsible not for quality, but for advising supervisors about lack of it. Only the one who can, through his subordinate employees, do something about raising quality can assume the responsibility for quality. This kind of line-and-staff relationship is often misunderstood and is therefore a frequent source of trouble in industrial production.

Since the supervisor is responsible for quality and is in charge of production, he must have control over those who cause quality to deteriorate. If the supervisor has no power over his subordinate employees, he cannot assume responsibility for the outcome. Although workers perform their jobs, the supervisor is still responsible for seeing that work is done properly. The supervisor always assigns responsibility to his subordinates, but that does not relieve him of it. If an employee ruins a valuable workpiece, management will blame the foreman, not the worker. Management personnel, including foremen, are always responsible for all the actions of subordinates.

Obviously, the one who commands must also have the right to pick, and exercise control over, the employee who will perform the job. Only with such powers can he account for his own actions as well as those of his subordinates. Responsibility without appropriate authority cannot produce satisfactory results. Unless an executive is granted adequate authority to carry out his responsibility, he cannot assume accountability for the ensuing action. Authority always implies adequate power of enforcement. If authority and responsibility are equal, the executive can legitimately be made accountable for the execution of projects under his command.

Although the concepts of authority and responsibility warrant more attention than has been devoted to them here, this should be enough to convey the idea that giving orders and demanding conformance are closely associated concepts. The point is that when managerial specialization takes place and managerial duties are carefully separated into line and staff activities, the original line authority does not change, because staff personnel never command performance. Line and staff separation begins with the growth of a company. Hence, any activities such as production planning, quality control, and process engineering, when performed by line supervisors, are line functions. It is only when it becomes essential, because of a sudden need for better and more effecttive management, to separate certain tasks and group them together under a staff department that these functions assume staff status. By the same token, some line functions, because of their nature as implied by the concept of authority, cannot be severed from the line. Planning functions can be very easily performed by staff people in a facilitative or advice-rendering capacity. Such intimate functions as picking the right person for the right job cannot readily be delegated to staff groups. Thus, of necessity, they are bound to remain with line personnel. Line executives usually become specialists in executing plans. Staff specialists tend to devote a large portion of their time to the planning of productive activities.

Generally speaking, the staff group is smaller than the operating personnel group, but their value is not less to the production organization than their counterpart in authoritative positions. The staff was created to increase executive effectiveness. As line duties become too extensive and executive work becomes too time consuming and complex, the time, energy, and knowledge of the individuals directing operations become overtaxed. When there is constant pressure and a lack of time to contemplate action, decisions are hurriedly and incorrectly made, which weakens the authoritative position. To counterbalance this, line members have staff assistants to render them specialized assistance and technical advice. Staff men have often collected and evaluated information and occasionally assumed very vital duties. Nevertheless, the preponderance of staff service falls in the general area of planning. Since staff specialists are associated with specific line departments, they usually function and act in the name of a superior line member. When the staff position is at a high managerial level and the resulting advice—frequently quite definite and sounding almost like an order—is directed at a lower-ranking executive, it should be construed to come from the next higher line executive rather than from the staff executive. Hence, it is not infrequent that instructions given by staff specialists carry an implied authority and have nearly the same weight as if they were issued by the respective line executive himself.[3] Specific plans are usually rubber-stamped by higher-ups. Thus, some sort of staff authority is created through introduction of direct authority relationships with coordinate line executives or with staff positions of lower managerial rank.[4] By means of such cross-arrangements, the volatility of information flow and advice is increased. As a result of such convenient arrangements, superior line executives are often relieved of annoying details to which otherwise a considerable amount of time would be devoted.

Although there are many staff departments in every large enterprise, our interest is limited to those departments which have something to do with the setting up of production plans. Whether these staff groups contribute directly or indirectly to the final plan of action is immaterial. Many staff groups merely supply other staff departments, such as production control, with the information necessary to carry out the production planning function. The planning which takes place in this latter department would not be possible without information which time study, process engineering, etc. turn over to the production control department. Hence, we shall restrict our attention to those staff groups whose primary task is to develop plans or accumulate and tabulate information upon which the planning process is based.

Since production requires action from line executives, it is justifiable to state that line executives specialize in putting plans into practice. Although the term "executive" is indiscriminately used in industry and may also refer to staff specialists, when used correctly, the term always implies presence of authority. The sole responsibility of running everything may become too great and the burden of responsibility may force the boss to delegate a part of his authority (not his responsibility) to others to run particular phases of his own duties. In pure line organizations, where activities are not distributed according to line-and-staff principles, the separation of activities follows the "cutting the pie" principle. Tasks are divided by the simple method of assigning sections of the total activity to others who receive authority commensurate with the nature of their position. This may follow the territorial principle or the product type of assignment. If executive specialization follows the product approach to splitting responsibility, it is conceivable that an executive is in charge of the production of Chevrolet automobiles, another of Buicks, another of Pontiacs, etc. Or if we use the principle of territorial specialization, we might say that a particular executive is assigned the responsibility and authority to direct the productive activities of the Detroit plant, another one the Pittsburgh plant, a third one the California plant, etc.

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[3] See page 98 on production control. The dispatcher turns over the job assignment to the foreman; the dispatcher is on a higher level than the foreman.

[4] *Ibid.*

In both of the above instances, territorial and product type of managerial specialization, the executive is responsible for every activity as it pertains to production in that territory or for that product, irrespective of whether reference is to production planning, organizing for factory operations, directing the employees, or controlling and coordinating the activities of others.

To these line executives are attached staff specialists whose specific function is to help and aid the respective line executive in the decision-making process. Staff people deal with highly specialized problems. At times even these activities may become so time consuming, multitudinous, and difficult that staff departments are subject to further division. This usually follows the functional principle of managerial specialization by which each staff group deals with certain types of problems. Obviously, as far as production is concerned, staff work is restricted to planning duties, which must necessarily precede production.

Among the various staff departments preference must be given to the production control staff, because it assumes the paramount importance in plant operations. Its extraordinary importance results from the fact that production control, among other duties, coordinates the activities of almost every other related staff department. Accordingly, production control is a "coordinative" staff function. This should not be construed to imply that the efforts of production control end at coordination; its coordinating activity is only a means to an end. The primary responsibility of production control is to set up feasible production plans. Planning necessitates, however, that much reliable information be gathered from other departments. These departments either develop or collect such information. This collection or pooling of information is "coordination" in the sense that efforts of others are brought together. Arranging the information in useful form is the process of "setting up plans." Consequently, production control is also the chief planning function. This department sets up finalized production plans based on information secured from other departments.

Now the question as to the other staff functions relative to productive activities must be answered. Here we should mention primarily the following engineering as well as industrial engineering departments: process engineering, methods engineering, motion and time study, and development of incentives. Furthermore, since we deal with production problems in advance of performance, we shall also be concerned with information gathered from sales forecasting, inventory control, or from other facilitative staff functions. They possess information vital to the development of effective plans.

When finalized by the production control department as already mentioned, the plan enables an orderly flow of production from start to finish. Figure 3-8 illustrates the relationship between the departments as well as that between the line departments of production and the staff function.

To reduce the weight of responsibility, serious decisions are turned over to committees. Although a committee cannot assume the responsibility of the executive who has to give the orders, it can facilitate decision making—especially because those who could make the executive account for his decision usually sit on the committee. The committee acts in the same capacity as a staff department to the executive in question.

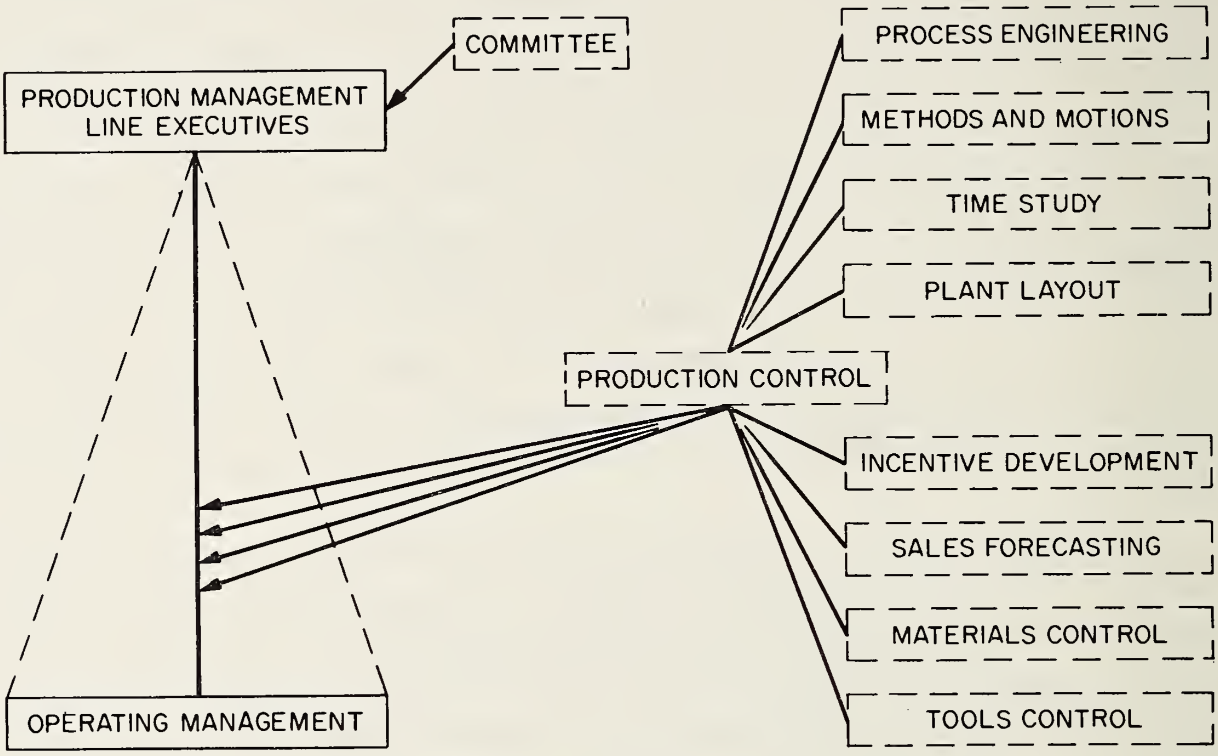

FIG. 3-8

Although the committee does not share the responsibility for action, it achieves practically the same end as if it did. If the recommendation of the committee is followed, the chances are that the executive responsible cannot be reprimanded.

LINE AND STAFF RELATIONS

At the risk of some repetition let us summarize the ideas which were laid down in preceding sections of this book. Production activities of industrial enterprises are managed by people who have either high or low rank in the management organization. The management organization may have been originally a pure line organization. Line members usually derive their authority to act and make decisions in the interest of effective production from ownership. This authority is passed down the line until the last operating level has been contacted. Thus a chain of managers is created. They see to it that the various activities necessary to combine raw materials and capital equipment with human labor are accomplished. The total activity is, in the field of production, called production management. While the pure line organization is an effective structure from the point of view of transmitting commands to subordinates, its inherent disadvantage is that it requires from line executives an extraordinary as well as complex knowledge. As long as we are dealing with simple products and production is on a small scale, the problems can be solved with the line structure, but when business grows and becomes complicated from the point of view of both production method and product complexity, it is essential to turn complicated problems over to staff people for solution. This creates the line-and-staff type of organization.

When staff personnel are attached to the line organization, as far as the outside is concerned, the decisions are still made by line members. But line executives are aided by staff specialists who give suggestions as to the advisable action or decision. Line executives are still responsible for the decision, even though it may have been the brainchild of a staff man.

The relationship between line and staff members is usually a cordial one. Since the staff specialists solve technical problems or render essential services needed by those responsible for production activities, their help and service are usually welcome to line people. Frequently, staff personnel are entrusted with research projects or investigation of some production problem. Since the facts are essential to arrive at a decision, line members need all the facts. They do not waste valuable time with time-consuming details or research. This is the area in which staff people work. When the answers are found, they are turned over to line executives, who use them in their decision making.

At times, the proper relationship between line members and staff members of management deteriorates because some line members fail to exercise their leadership as they should. Some executives frequently let staff men make their decisions. Thus, decision making might become a habit with staff specialists. Where staff men make authoritative decisions, we might assume that a misuse is made of authority. (This should not be confused, though, with the case of overlapping authority.) This is an illegitimate assumption of authority to take action. Such instances are frequent in industrial enterprises where production involves the direction of highly technical activities. In the chemical industry, for instance, chemists may be in charge of quality. Although line supervisors are capable of giving production orders, their background in chemistry and chemical processes may be limited by lack of schooling in sciences. While chemists are not empowered to interfere with production, they tend to give direct orders to employees. Although such "professional interference" is understandable, it is an improper application of the concept of authority. Obviously, such instructions should always be given by the line supervisor. The main idea behind the line-and-staff organization is that the line position must be strengthened by competent technical advice—not destroyed.

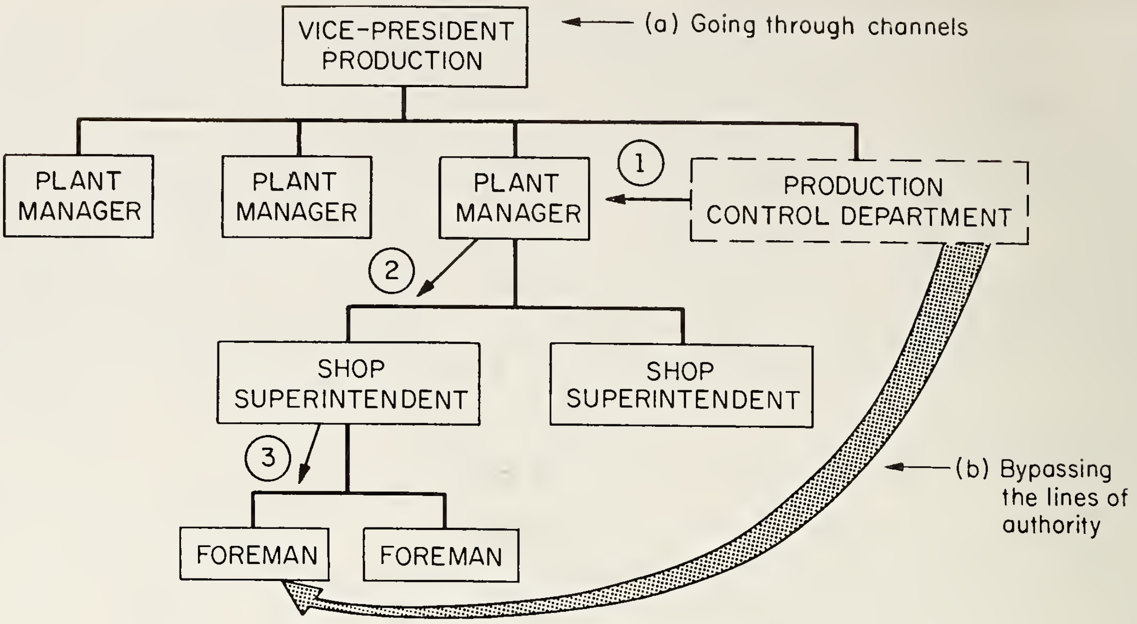
VICE-PRESIDENT PRODUCTION
(a) Going through channels
PLANT MANAGER
PLANT MANAGER
PLANT MANAGER
①
PRODUCTION CONTROL DEPARTMENT
②
SHOP SUPERINTENDENT
SHOP SUPERINTENDENT
③
FOREMAN
FOREMAN
(b) Bypassing the lines of authority

FIG. 3-9

It is true of course that, in practice, certain methods are developed which virtually put staff people in a position of implied authority. This is done for the sake of expediency and to facilitate the flow of information from top to bottom. Because of the complicated nature of production, plans are developed by staff specialists. These plans take the form of production work orders, production schedules, change-of-sequence notices, etc. The proper way to pass on such information to those to whom it is directed would be to turn it over first to the appropriate line executive, who in turn would issue directives based on the information. Yet such an interrupted flow of information would hinder effective production. Therefore, any staff man who passes on information to a lower-ranking line executive may have the implied authority of the respective higher-ranking line executive. In the form of a diagram it would look like Fig. 3-9.

Thus, out of a cumbersome three-step procedure, a simple one-step information flow is created. Although the line executive does not have to accept the plan thus transmitted, lower-ranking members in the organization do not usually argue with high-ranking staff specialists, in view of the fact that the instruction could go through the line just as well. They usually follow the plan received from the "higher-ups" regardless of their line or staff character. At times, however, this concept of expediency in information flow from staff to line is misunderstood and staff members exercise a more or less direct authority over the lower-ranking line members. This is an inappropriate practice.

SUMMARY

PRODUCTION PLANNING AND EXECUTION

Production of complicated products requires the knowledge of a team of men. A production executive divides the total managerial activity into specialized activities, delegates the work to subordinates, or apportions problems for solution to staff specialists. Subsequently, the same executive pulls together the efforts of the various subordinates. No executive can possibly know everything necessary to the production effort, but by pooling the efforts of many, the production problem, no matter how complex, can more easily be solved. Apparently,[5] an executive is good when he can make a smoothly functioning team out of people with the many different skills required in the operation of a modern business. He must plan and organize and integrate in every situation he meets. His most important function is to reconcile, to coordinate, to compromise, and to appraise the various viewpoints and talents under his direction to the end that each individual contributes his full measure to the business at hand.

The executive and the planners are usually two different groups of men in modern industrial enterprises. The function of the executive is to command performance and carry the responsibility for the result, even though production may have been planned by staff specialists. In this way a division between planners and executives takes place.

AUTHORITY AND RESPONSIBILITY

Those who possess authority to act are the line members, and those who set up plans but have no responsibility for action are the so-called staff specialists. The staff specialists work for the line executives and solve their complicated problems. In many instances, owing to lack of specialized training, executives could not solve problems even if they had sufficient time to do so. It is to strengthen the position of the executive in charge of production that staff specialists are attached to the line organization. A close cooperation between these two groups of men guarantees effective performance and economical production.

It is important to note that those engaged in planning work or investigation seldom do things without a request from line executives. The staff specialist offers advice and turns information over to executives. The line executive can take it or leave it. If he accepts the advice or the plan developed by staff groups, the line executive is responsible and accountable for the ensuing action. If the plan brings success, he takes the credit for it; if the plan fails, the blame is his. Although this seems to be unjust, it is the best system yet devised to ease the problems of overburdened and therefore less effective executive leadership.

A large portion of executive work is performed by subordinates, since line executives delegate part of their duties to subordinate people. Although duties are turned over to others, the delegator is still responsible for the activities of his subordinates. Thus, while delegating authority to subordinates, executives are not relieved of their own responsibilities for the outcome of production.

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[5] C. H. Greenewalt, "The Management Profession," *Advanced Management*, December, 1955.

Any good executive is able to work through the people. This means that executives pool the specialized skills of men toward preestablished goals.

In companies without formal line and staff separation of managerial activities, functions delegable to staff are usually handled by line members along with their ordinary duties, probably on a part-time basis. Line members may turn to one another for specialized advice. For instance, a line officer who may be something of an expert in industrial engineering may devote a portion of each day to line duties of his own and the remainder of the day to staff duties. For this reason, it is frequently difficult to differentiate between line and staff duties. Nevertheless, theoretically there is a difference between the two activities. In pure line organizations, every managerial activity is line activity. Planning, organizing, directing, controlling, and coordinating the activities of others are in the hands of those who are in charge of production.

QUESTIONS

3-1. What do we mean by "violation" of the span-of-time, control, and knowledge principles?

3-2. Is it advisable to have dual authority over a subordinate?

3-3. Is it good to have a great responsibility, but little authority to command performance relative to the action for which one is responsible?

3-4. What are the functions of a production executive?

3-5. How does the task of a production executive differ from that of the production foreman?

3-6. What is meant by planning, organizing, directing, controlling, and coordinating a) at the production executive level, b) at the superintendent level, and c) at the operating management level?

3-7. How does managerial specialization take place in the field of production?

3-8. Is specialization of managerial activities into planning and execution justified?

3-9. How is it that staff planners have no authority and yet are able to function satisfactorily?

3-10. Which aspects of planning cannot be delegated to staff personnel?

3-11. Is it true that every management function is originally a line function?

3-12. When is a separation of line and staff activities warranted?

3-13. It is said that specialization is necessitated by the limited spans of knowledge, control, and time of managerial personnel. (This is supposed to apply to both line and staff personnel.) If this statement is true, why is it so?

3-14. How is it that a staff group of a higher level can give orders to line personnel of lower managerial levels without violating managerial principles?

3-15. What kind of work is assigned to committees and what weight is carried by committee recommendations?

3-16. What difference does it make whether advice was given by a staff man, a committee member, or an outside consultant?

3-17. What is the function of those who plan the whole production process?

3-18. Why do line people not plan the production from start to finish?

3-19. In which type of enterprise is production still planned by line personnel?

3-20. How can a planner, or group of planners, influence the outcome of production?

3-21. How much authority must a production foreman possess to be able to assume responsibility for the actions of his subordinates?

3-22. How does a production executive exercise control over production activities which take place in the shop if he himself sits in an office far away from the shop?

3-23. How does the foreman control and coordinate the activities of the workmen?

3-24. What are the major staff departments that plan a large part of production activities?

3-25 In what sense is a "plan already action"? (The quotation is from Henry Fayol.)

3-26. What is the relationship between a) planning and control, b) control and coordination, and c) direction and control as far as the production activities of an industrial foreman are concerned?

3-27. What is the exact meaning of the term "organizing" as far as a) the production foreman, b) the plant superintendent or plant manager, and c) the vice-president in charge of production are concerned?

3-28. What characterizes a good plan?

3-29. Is it more difficult to a) set up production plans or b) put them into practice?

3-30. Which of the three line executives has the most difficult duty: a) controller, b) production executive, or c) sales executive? Support your choice.

PROJECTS

3-1. Imagine that a) the president, b) the vice-president in charge of production, c) the plant superintendent of one of the company's plants, and d) a particular production foreman at DuPont, Westinghouse, General Motors, General Mills, or any other company goes to his office. 1) Describe the activities of the above company officers. 2) Compare the activities of the various men. 3) List the similarities and dissimilarities between their daily duties.

3-2. Procure the yearly stockholder report from the above-listed companies and on the basis of the organization chart, list the various line executives, middle and operating managers in line positions. Then make a separate list of the staff people who are concerned with production in one way or another.

3-3. Since the company has never before produced anything like an airplane, tell us how you would go about creating your organization, planning the production activities, directing the production activities, and controlling the achievement of results and how you would coordinate the efforts of your subordinates. Set up an elaborate plan.

3-4. It has frequently been stated that industrial foremen are a part of management, but they are seldom granted all the rights, privileges, and authorities which any member of management should possess.

Using the following points as an outline, explain why this is true or why you disagree with the above statement.

a. In almost any company we can find employees under the supervision of foremen who earn (including bonus payments and fringe benefits of all kinds) more than the industrial foreman.
b. It is nearly impossible to devise a plan for payment of industrial foremen which would in fact compensate them in such a manner that they earn more than the best-paid employee.
c. Foremen seldom consider themselves to be managers. As a matter of fact, they identify themselves more frequently with the labor group than with the management group. Furthermore, they feel more often than not that they have no say in hiring or firing people and that their responsibility ends in delivering performance without possession of authority.
d. Foremen feel that they cannot assume responsibility for performance of their subordinates because in more instances than not the personnel department hired the worker without waiting for their OK.

3-5. Outline your views as to what the qualifications and skills of a typical industrial foreman or supervisor should be a) in a small company and b) in a large company.

Do you believe the foreman should possess specific technical skills (such as running machines, knowing chemistry, planning, and determining work requirements), or should it be sufficient that he knows how to deal with people?

It has been stated and restated that supervision in large companies is nothing else but handing out work assignments to people and seeing to it that the employees conform to the production requirements and directions in general. If this is true, explain whether or not a college graduate with a business administration degree could be trusted with a supervisory position.

CASES

3-1. The Electronic Company (Part I).

The company is a partnership owned and operated by Ralph and Kathy Budelman. Mr. Budelman has had extensive experience in the electronics business, since he spent half of his life in the employment of large firms in this field including General Electric, RCA, and Westinghouse. When he finally went into business for himself, he knew everybody in the electronic field and was acquainted with bidding procedure as well as with many technical matters. Although Mr. Budelman is not an engineer and had little technical training, he nevertheless has a good sense of technical comprehension. His wife, his former accountant, holds a degree from Wellesley College and was a CPA in Illinois.

Kathy and Ralph entered the field of military electronics because the government was a good, steady customer. Also, when one works for the government, one does not have to entertain a large engineering and research department and no advertising or sales manager is needed. Furthermore, manufacturers of military items can receive loans which are guaranteed by government agencies. From the practical point of view, the Budelmans thought that having a government inspector on company premises (the military keeps a resident inspector on company premises) would relieve them from hiring inspectors of their own. While most producers dislike this arrangement, the Electronic Company appreciated the quality control services which such an inspector can render.

Since Mr. Budelman knew the right people at Signal Corps and other armed services agencies in charge of purchasing communication devices, it was relatively easy to go into business and get a few contracts provided, of course, that the company could bid, produce, and deliver at competitive prices. At first everybody worked—even the boss was packaging and testing. Mrs. Budelman took care of the books. The devices produced were simple, and some were subcontracted from producers of large units of communication devices. The company merely purchased the machined parts, cables, wires, etc. from other producers and assembled them with hand tools. The Electronic Company was really an assembly firm. At that time, the soldering iron was the most complicated work tool. The company employed mostly semiskilled employees at low wage rates; many were female workers.

The company prospered mostly because the supervision was excellent, the company was compact, and the employees were few but loyal. The female workers could be kept under constant surveillance. Loafing, conversation, and other time wasters were kept at a minimum. Even if there was some conversation at the assembly benches, the nature of hand assembly is such that conversation does not hamper production.

With such a simple organization, the company achieved considerable success. Profits were approximately 10% on the invested capital, and although occasional losses were suffered, profits very easily covered the losses. The problem of losses originated primarily in a lack of engineering personnel. Overlooking certain technical details caused erroneous bidding. Hence, costs were frequently higher than estimated. But since the assembly work was simple and the items produced were relatively cheap, the errors were seldom too serious and the losses were correspondingly small on each item. All in all, the company prospered throughout the years. The first sign of trouble appeared around 1960, when the company ran out of work. It was difficult to find suitable work to keep the plant and its employees busy. At that time, Mr. Budelman decided that the time had come to enter a more complicated field and decided to take on bigger jobs which required greater skill and more physical facilities. Such jobs were usually available, whereas for small items there was too much competition among the many small electronic outfits.

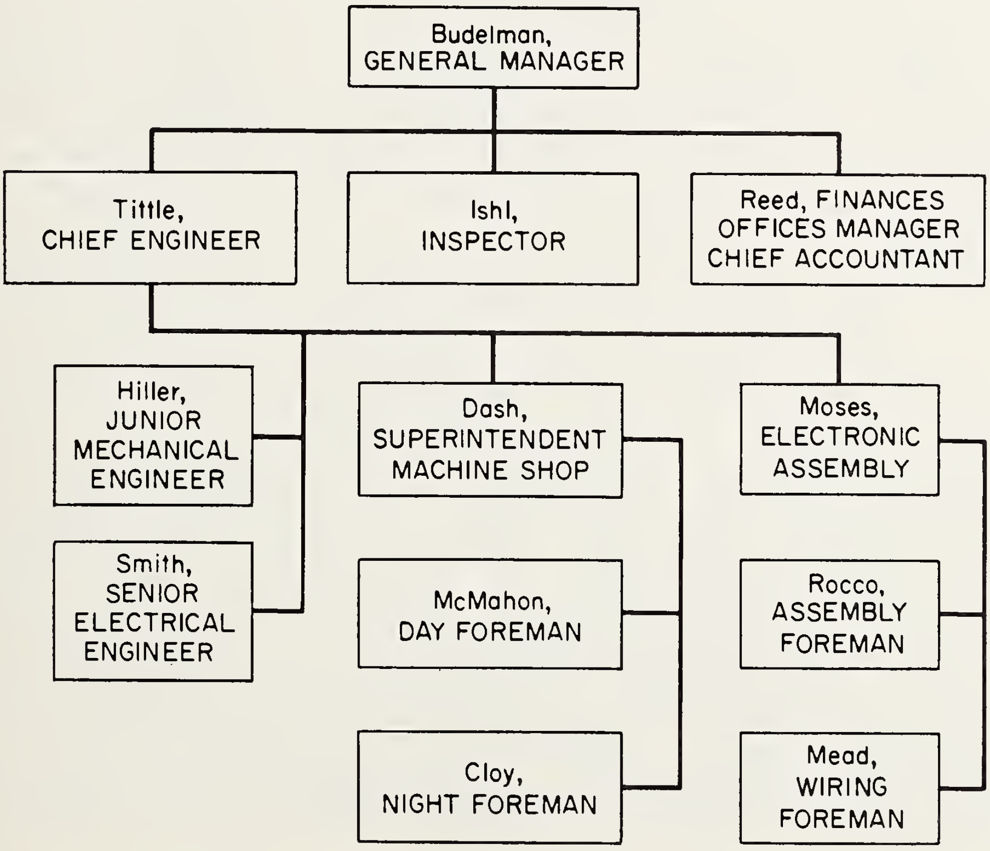
Since larger contracts for complicated units were available and most of the larger companies still had a sufficient backlog of work, even the "little fellow" could enter the field. For these purposes a chief engineer with both electronic and mechanical backgrounds was hired. Mr. Tittle was an excellent man who had both production know-how and long years of designing, processing, and estimating experience with large companies. While his talents were undisputed, his personality was "rough." His language was not much better than that of a laborer, though he had graduated thirty years before with *summa cum laude* at California Tech. His knowledge and technical background were so good that everybody got along well with him despite his personal shortcomings. Since cost development and efficiency interested Mrs. Budelman, disputes between Mrs. Budelman and Mr. Tittle were frequent, but they never came to the boiling point because she knew that the partnership needed a man like him. When Mrs. Budelman complained to her husband, he usually replied, "This is a business enterprise, not a tea party." But the problems were aggravated when two foremen and two superintendents were hired. Although they recognized Tittle's superior knowledge in production problems, they frequently functioned better without his advice than with it. Arguments were now very frequent, very heated, and very annoying, and they had definitely affected production and employee morale. Mr. Budelman was often reminded that Tittle interfered too much with production, but he believed that Tittle was more or less the boss over production, except that now his time was taken up by developing processes and writing out bills of materials, in addition to his duties of working up cost calculations. The fact is that Tittle's duties were never specifically stated. Among other work, Tittle did most of the legwork as far as bidding was concerned. He frequently sought the opinions of supervisors who had some experience with specific jobs. These inquiries were mostly about possible costs and other matters, such as time requirements, methods of doing the work, and raw materials requirements. Although time study data were not available, Mr. Tittle's labor cost estimates came pretty close to actual time and cost requirements. Although his estimates were based on guesswork, losses resulted not because his estimates were wrong, but because Mr. Budelman revised them at the last minute.

It was Mr. Budelman's worry and responsibility to solicit new business. When competition was rough, he had many friends in the industry who passed on to him information about who was bidding for a new job. Depending on how hungry the other companies were and how badly Electronic Company needed the job, Mr. Budelman revised the bid to make certain Electronic would be the lowest bidder. Since outbidding others is more or less guesswork, he often acted on hunches. The only trouble with his method was that he was using compound percentages and, by doing so, he brought the cost estimates fully out of balance. Finally when the company was awarded the contract, it was discovered that a loss was inevitable. Then supervisors were told how much time they could spend on each job. Thus, a time budget was established arbitrarily. When they stated that it was impossible to produce the parts and components so fast, arguments developed between supervisors and Mr. Budelman, who referred them to Mr. Tittle, who made the bids and estimated production time. "Are you a complete fool," asked one of the superintendents, "to demand production of an item in twenty minutes when you know very well that it takes nearly that long to put the workpiece into the machine, let alone perform the operation itself?"

Although Mr. Tittle knew why the production time estimate was out of balance, he did not mention to the complaining production people that his original estimates were all right, except that the boss was manipulating the cost estimate figures. He has never revealed the real causes, for which Ralph Budelman has kept Mr. Tittle in high esteem. His integrity has always been beyond doubt. In frequent arguments of this kind Tittle was the centerpiece, and in this capacity he often insulted and threatened to fire the supervisors. Somehow the supervisors could not figure out his position in the company. He did engineering work, came to the shop, snooped around and criticized every supervisor, stopped employees, and frequently ridiculed supervisors in front of employees. Thus, such a situation developed that employees defended themselves by saying, "Mr. Tittle said that I should do it this way, and not the way you said." While that was often untrue, a few actual incidents had made it credible. Because of this friction, the authority of the supervisors suffered in the eyes of the employees. Losses are larger because the cost of the items produced was correspondingly higher. But when profits were made, they were also large. Thus, despite losses, the books of the company showed rising profits.

When business in general sharply declined in 1960, the Electronic Company, among many other firms, ran out of work with the exception of a few small orders. To alleviate the situation, EC was forced to apply for big and complicated jobs. Finally, the firm landed a large order which could be produced on a large-scale basis more or less continuously. It would keep the plant busy one to two years. The order turned out to be profitable and the company established itself in the industry as one of the best producers of communication devices, such as field telephones, switchboards, military microphones, and other units used in communications and the missiles program. While production was fairly profitable, not everything was as bright as it appeared on the surface. Disagreements between Tittle and the machine shop superintendent, Mr. Dash, were frequent, but since it was Tittle who had brought Dash into the company, the latter always conceded to Tittle without argument. As far as technical knowledge was concerned, Mr. Dash was just as sharp as Tittle. In the practical sense he was far superior to any graduate engineer including Tittle. Because Mr. Dash had no degree, he lost many arguments on an academic basis; but he won most of those concerned with shop practice. He was an excellent mechanic and tool and die maker, and he could develop designs and processes better than Tittle could. However, Tittle's reputation was so great that Dash was frequently defeated when processes and designs were decided upon. It was little consolation to the company to discover that Dash was usually right, because by that time losses had already been suffered. The parts which Mr. Dash's department, the machine shop, produced by following Tittle's ideas did not fit as well as they should have fitted, and quality began to fall. As a result of these arguments over parts which were out of tolerance, the government inspector, Mr. Dash, Mr. Tittle, and Mr. Budelman had serious arguments. The government man did not put his approval stamp on the products, which meant that the company could not ship them. The products had to be taken apart and repaired. This caused delays in deliveries that involved sometimes penalty payments. Although Mr. Dash agreed with the inspector, once he had produced these parts he had to convince the inspector that the parts would hold up in actual use and that they were good enough to be placed in the finished communication units. A peculiar situation had developed; Mr. Tittle decided the method of production and the process, and Mr. Dash was blamed if parts or components were faulty.

Despite all these problems, the company as a whole was making a profit, but overtime work, delays in deliveries, excessive costs for inspection, and rework had cut deeply into that profit. Taking into consideration that the company had been in this line for such a short period of time, it produced large devices remarkably well. It has to be recognized that as far as large and complicated devices were concerned, the company was still inexperienced and the losses which might be suffered were considered as "tuition fees" by Mr. Budelman. He was still happy that his organization had beaten the problem of transition from small items to large ones and that he could now move into a larger plant. He had acquired a few dozen fairly large-sized machines such as milling machines, shapers, large presses, press brakes, punch presses, and grinders. He knew that once the company gained experience, the problem of production would be solved forever. But the first big job in the new plant turned out to be a flop. Costs of production were considerably higher than estimated, and cost accounting showed a loss of 8% on the price of each unit. The company called in a consultant who was told that the situation was bad and that the company had no system. The consultant asked first for an organization chart. Since there was none in existence, Mr. Budelman made up the one shown in the accompanying illustration.



Apparently, the whole organization was badly conceived. No one knew clearly who was supposed to be responsible for which activity or what authorities and responsibilities were allocated to the various company officials. In addition to the existing misunderstanding, Mrs. Budelman had come in to work on the books. She became more and more frustrated at the rising costs.

She predicted, though she would not admit it, that the company was running toward disaster; and since she was the other partner, she was rightfully concerned. On a $5 million contract an 8% loss might wipe out the company. Unless the present rate of losses could be stopped and the situation reversed, the owners would lose their capital investments. The task of the consultant was to see to it that ways and means were found to get the company out of its precarious situation. Mrs. Budelman hoped to solve the problem by making observations, but by doing so she interfered with the various managerial activities. Thus, for instance, she started to go into the shop and ask employees why they were not working. Then she usually turned to the two production superintendents and reprimanded them, adding, "No wonder we're losing money." The situation was so bad that Mr. McMahon, the machine shop foreman, threatened to resign.

The consultant went to work, and even he was requested by Mrs. Budelman to pass judgment on certain issues between herself and the various members of the management team. Furthermore, Mrs. Budelman started to urge the consultant to do something faster about improving the company's operations. The effect was so far-reaching that the consultant had to hide when he saw Mrs. Budelman coming.

After months of study, the consultant among others discovered that production decisions were made primarily by the superintendent of the assembly department and his foremen. For example, the superintendent of the assembly section asked the machine shop foreman or its superintendent for anything he needed to keep his line busy. Often the situation was so tragic that lack of parts would be discovered only an hour before assembly would actually run out of them. Since the parts had to go through several different operations and more often than not machines were busy with something else, it was seldom possible to produce the needed parts immediately. Thus, either the assembly had to stop or the product in the assembly process had to advance toward completion without that part. When a few days later the part was available again, backtracking and extra work had to be expended on each work unit. During the resulting storage time, some of the electrical connections would loosen, and this would be found out only during the final inspection. An elaborate process was then necessary to discover the bad connection. Frequently it was cheaper to take the whole unit apart completely rather than to look for the bad connection. As a direct result of shortages in components, delays and rework were so frequent that, according to the time study data established by the consultant, production output of the assembly line was less than 50%.

Frequently the need for production was so desperate, especially when the end of the month came and certain products had to be shipped (to avoid penalty payment on the one hand and in order to bill the customer before a predetermined deadline on the other), that the machine shop at the request of the assembly section dropped everything but the contracts in question in order to complete the parts urgently needed. Machines were stripped and reset again for the more important jobs. Since parts ran out periodically, this kind of situation repeated itself time and time again. The efficiency of the machine shop was just as poor as the efficiency of the assembly department. The above-mentioned unpredictable changeovers, short runs, and frequent shifting of employees from job to job created all sorts of inefficiencies. In addition, when such rush setups had to be made, it was the foreman who had to assist in setting up the machines. While he was busy with a setup, employees running out of work during this time had to wait for the foreman—and meantime do nothing.

Because the consultant planned to time study a given operation during a Monday morning, he kept an eye on a specific machine allocated for a specific work during that morning. As he went from job to job making time studies, it occurred to him that the job which, according to the departmental foreman, should be worked on had not yet commenced. At least 55 minutes must have passed in the meantime. When the consultant bumped into the foreman as he passed by, he asked about the job which was supposed to be running that morning. The foreman said he was under the impression that a girl had been working on the job for the past hour. Finally, a search through the plant showed that the employee was reading a magazine in the ladies' room instead of operating her machine. The busy foreman had evidently failed to notice her absence from the shop floor. Employees at the Electronic Company were left pretty much on their own, and they were the ones who determined the method of performing the work assignment. Furthermore, in the absence of time studies, no one knew what a good day's work was. That subsequent time study disclosed that some machine shop workers turned out only one or two hours' work during an eight-hour day was not too surprising.

With all these discoveries the consultant formulated some of his recommendations to management, including the need for time study, production control, and control over employee performance. In the past little, if any, organized attempt had been made to get efficient production. Mr. Budelman merely looked at dollar volume of business rather than at how that volume was achieved. Thus, when he needed, say, $200,000 billing in one month to cover his running expenses for the next month, he arbitrarily decided that the shop should turn out, say, 200 units of X-15's and 150 units of Y-229's. That capacity utilization varied with the item worked on did not enter his mind, and it was up to the two superintendents to figure out how the work could be done. He felt that it was their job to plan and carry out production plans. Although Mr. Tittle should have known better from his great experience with production, he backed up Mr. Budelman's requests. Mr. Moses and Mr. Dash usually complained that they had been asked the impossible. The fact of the matter was that such a quantity might have been feasible, but an expert production control man was needed to determine production schedules weeks and months ahead in order to attain certain predetermined goals. Haphazard planning just could not accomplish these requirements without the frequent necessity for overtime work and pay; delays and problems became so severe that cost got fully out of line. Thus, when just about half of the contract was shipped, the financial losses no longer permitted payment of bills owing to lack of adequate working capital. The difficulty experienced with payment to suppliers of steel, aluminum, parts of all sorts (wires, cables, etc.), resulted in irregular raw material shipments to Electronic. Thus, when the assembly ran out of parts, the machine shop was unable to produce them because needed raw materials were not always at hand. The suppliers in a number of cases refused to ship unless the goods shipped were prepaid. Situations like this usually held up production for a few weeks. To remedy the situation, the office manager-chief accountant suggested what should be produced to get the most income out of shipments. However, his suggestions turned out to be fictional, since he usually suggested goods for which materials were not available. More realistic suggestions were advanced by Mr. McCormick, the purchasing agent, who usually knew what materials were arriving or available in the storage room.

As the losses grew and the methods introduced by the consultant started to diminish the "loss increments," the problems of the company took a turn for the worse. Although at the time the materials and production control systems introduced were worthwhile, it was apparent that the serious organizational question had to be solved before the scientific management methods could bring the results expected.

A further aggravating factor was the problem of inspection. When management experienced difficulty with quality, it was decided that it was essential to hire an inspector. At the suggestion of the consultant, the inspector operated independently at first. Finally, he was placed under the supervision of the shop superintendent, who had lately become a very important member of the management. The reason for this was that his department started to show profits and the losses could now be attributed more or less to the assembly department. However, this was more fiction than fact. What had really happened was this: When the government inspector held up shipment, the newly hired inspector spoke with the government inspector about the problem. When it was discovered that assembly was working with defective parts supplied by the machine shop, he began to concern himself mainly with production of parts. He stopped operators right and left and employees no longer knew whether the inspector or the foreman was their boss. The inspector was a highly qualified man and rejected every workpiece which was not up to specifications. It happened several times that, out of a hundred workpieces, he passed only ten as acceptable. Mr. Budelman became alarmed, since this meant not only loss of money in the sense that materials were scrapped, but also loss of labor time. He spoke to the inspector and he discussed the matter with Mr. Dash. As a result of the conversation, the inspector became directly subordinated to Mr. Dash.

Although the case of the Electronic Company does not end here, the function of this case is fulfilled. There are many details which have been left out, and in a later section some of them will be described. However, here the organizational aspects of the case are emphasized.

Questions. The case primarily illustrates problems involved in poor organizational and management practices. It is the function of the student to discover where the trouble spots are. The student should try to be impersonal. One should deal not with a person but with the situation. Obviously, the situation might be brought about by people; nevertheless, the problem here is a result of lack of proper application of principles of management. Some of the problems are the result of misapplications of principles rather than problems in themselves. Thus, begin the analysis as follows:

1. What are the symptoms that this company is in serious difficulty? (Be careful with your analysis; do not mix time periods; during a certain period, certain symptoms exist.)
2. In the same way that you listed the symptoms, list what causes those "bad things." (Check whether or not you have confused cause with effect; if so, correct the list accordingly.)
3. Suggest solutions to the problems which you have found. (Although there may be numerous suggestions, be careful that your suggestions agree with accepted principles. If your suggestion is out of the ordinary, explain why you think that your suggestion is better than the principles.)
4. Who is at fault in this case?
5. What are the principal errors which were committed here by Mr. Budelman, Mr. Tittle, Mrs. Budelman, and Mr. Dash?
6. Which management principles were disregarded in this company. Is there an excuse for the situation?
7. Can the problems be attributed to poor management, inexperienced leadership, or to other causes?
8. Should there be more paper work and organized control in this organization?
9. If you were in Mr. Budelman's shoes, how would you have acted?
10. If you were the consultant, what suggestions would you have made to solve a) the organizational problem and b) the other problems?

3-2. Ward and Bailey Company

A one-time top producer in the meatpacking business, Ward and Bailey Company of Chicago, gradually fell to a money-losing position. It was difficult to pinpoint the reasons for the decline, but customers depicted the "present," as opposed to the "famous," Ward and Bailey as high-price meat packers selling low-quality merchandise. Within the company almost everybody agreed that the decline could be attributed to the fact that Mr. Bailey, the president of the company, ran the business just as his predecessor ran it back in the 1930s.

Since Mr. Bailey did not believe in decentralized control, every major decision and often minor decisions had to receive his personal approval. As long as Mr. Ward lived, company operations were favored by the wartime demand and by a distinct separation of responsibility between the two owners. Although Mr. Ward was the president, he concentrated on the production end of the business. There was a tacit agreement between the two owners that each one would stick to his specialty. Thus Mr. Ward acted as a coordinator of all the production functions and approved, without much contemplation, all the decisions which Mr. Bailey made with regard to finance and marketing. At the time Mr. Bailey was the executive vice-president.

The organization was suited to the company's operations, and the enterprize prospered during that time. However, when the company acquired the Owens Company, conflicts between the management of that plant and the home office developed. The home office wanted to run the Owens Company by long-distance telephone. Although production was still profitable, the high degree of centralization of authority in two hands began to show signs of weakness. Nevertheless, the company operated efficiently enough to show consistent profits. This was primarily due to the superior technical and processing know-how and knowledge of Mr. Ward, who had formerly been a very successful butcher. The result was that the company could sell at competitive prices enormous quantities of various meat products. Since the company was at the time operating on a three-shift basis, it was not infrequently that a night foreman or superintendent called Mr. Ward during the night to obtain his approval of some production decisions. Though inconvenient, this form of organization was apparently well adapted to small-scale as well as large-scale production of meat products.

When economic conditions returned to normal after World War II, but especially a year or so after the Korean War, price competition became a serious problem with which the company could not cope. This situation was aggravated by two strikes which could be solved only by granting substantial wage increases to company employees. Hence, the decline started with lack of technical modernization, rising labor costs, and with the death of Mr. Ward of a heart attack at the age of 58.

Profits nosedived immediately after Mr. Bailey took over the presidency of the company. Since his talents were not in the production end of the business, he could not see the need for the replacement of obsolete production facilities with new and more efficient machinery and plant equipment, and in general he was against any costly innovation. Suggestions made to him by production engineers, superintendents, or outsiders were turned down.

Mr. Bailey claimed that, because the labor union had become so powerful, he purposely avoided installation of labor-saving devices to prevent labor trouble from developing. To avoid any conflict, he discussed every problem, from big to small, with the business agent of the union involved. Through his personal contact, he was able to forestall any future wage demand. Otherwise, he claimed, the company could not have sold at competitive prices. In his eagerness to keep labor peace, it was not unusual that he himself rehired employees fired by their supervisors.

The meat market had increased as a result of sustained prosperity, but in a competitive market it was difficult to undersell giants like Oscar Mayer, Swift, and Armour. The competitive price depended on low costs which the company was unable to achieve. In the production shops loafing became commonplace and disciplining employees was nearly impossible, since supervisory personnel were frequently overruled by higher-ups.

In face of rising labor cost, Mr. Bailey stopped replacing high-priced executives or supervisors who retired, died, or left. Thus, the number of supervisors decreased and the remaining foremen and superintendents became overloaded.

Since the American market was too competitive, Ward and Bailey planned to sell on the European market. For this purpose, the company made arrangements with Argentinian cattlemen and a European meat-packing house. According to Mr. Bailey, this operation could compensate for the deficit on the domestic production. In order to supervise the operations of this new meat-packing business, he went to Europe for six months.

As his substitute, he appointed his son-in-law acting executive vice-president, and he gave orders that he himself should be kept in touch by transatlantic telephone conversations. The new acting-vice president found himself in a difficult position. All too soon he discovered that none of the management personnel had sufficient authority to run their departments independently. Practically every decision had to be made by him. The plant superintendent proposed certain production improvements and wanted the acting executive vice-president's approval. Then the accountant came in and wanted to discuss a new depreciation method which might convert losses into profits through a bookkeeping method. The sales manager kept coming in with petty problems. Although the acting executive vice-president did not receive clearly outlined powers as to how to run the company, he felt that since he was in authority, he should effect minor reorganizations. He called in all the department heads and outlined to them their sphere of responsibilities. He specified what type of decision they should consult him on.

Under this new arrangement, the production superintendent could do everything in his power to improve the efficiency of the meat-packing operations. Consequently, he introduced a new slaughtering system. The outmoded slaughtering method was replaced with a relatively inexpensive method requiring few innovations. Thus, the handling of struggling, squeeling, and panicky hogs, shackled and hanging by a hind leg from a conveyor chain, was abandoned. Instead, hogs were led onto a conveyor belt that carried them through a tunnel containing an odorless, nontoxic mixture of air and carbon dioxide gas. With this method further operations were greatly facilitated because each hog dropped to sleep within minutes and was carried unconscious to the slaughtering chambers. Although the present volume of business did not warrant such a technically superior method, the superintendent assumed the full responsibility for the excess capacity. He stated that the method tended to cut production time by 50% and thus halved labor costs in some of the separation stages. The tunnel can immobilize up to 600 hogs an hour; the same number took 4 hours to slaughter under the old method. The system was not only a better method because it accelerated production, but it allowed smooth, nonbruising handling methods that improved meat quality to the point of perfection.

Suddenly improvements and production efficiency started to go up, supervision became easier, and the situation seemed to get better. When Mr. Bailey arrived from Europe, the company's operations had started to show profits.

Questions. The student should be reminded that production problems and productivity do not necessarily originate in the production shop. They may be connected with administrative decisions and organizational shortcomings. The student should analyze the case problem by using the normal approach to case studies: symptoms, causes, solution.

1. What are the symptoms that something is wrong with the company?
2. What are those symptoms which can be noticed only if the student contrasts Ward and Bailey's organizational practices with those dictated by accepted principles?
3. Once you have listed the symptoms which point toward the problems to be solved, list the causes of those symptoms.
4. Suggest solutions which would eliminate those causes.
5. Based on the happenings while Mr. Bailey was in Europe, do the son-in-law's solutions dovetail with your own?
6. If you were a consultant, what would you suggest to management to bring the company's operations back on a profitable basis?
7. Had Mr. Bailey's personality something to do with the state of affairs in the Ward and Bailey organization?
8. If management principles were violated in this case, list them and state what should have been done.
9. Would you call the son-in-law a better or worse manager than Mr. Bailey? Why?
10. If you were in the son-in-law's position, what would you have done during Mr. Bailey's absence?

3-3. The National Equipment Corporation

From a small machine shop repairing industrial equipment, the National Equipment Corporation grew to a corporation of considerable importance in the machine-producing industry. The company had a large engineering department where the machinery was designed by company design engineers (mechanical engineers) and a score of draftsmen. However, the company accepted orders without contracting to draw up the design of the machine. The main product of the company was "special-purpose equipment." Usually, manufacturers engaged in large-scale production came to National Equipment Corporation requesting them to design and build machinery for their production line. These units were complex and fast-operating machines. With the exception of truly special designs, some similarity existed between certain types of machinery; primarily, the arrangement of the tools to the frame was different. Although engineering design considerations were considerable, the tailor-fitting of tool arrangements was not as complicated as the company presented it to the customers. Very often it was accomplished by selecting several standardized toolheads which varied in the positions, speeds, feeds, and the like assigned to them. In these instances the special-purpose preparation was reduced to designing the frame which holds the head at the special location and angle. Hence, in spite of some variation, many of the parts manufactured by the company were of standard designs and were adapted to the customer's specifications. Therefore, the company was not necessarily an intermittent producer, but operated to a considerable extent as a repetitive producer of similar items. This repetitive nature of the production process primarily applied to the machine shop work and not to the other departments.

The company was engaged in repair work during the last war, when replacement parts had to be made quickly and precisely. Toward the end of World War II the company added smaller machines to its line of products. When it received a big order to design all the machines for a new plant in 1962, the company established, in addition to the machine shop, an assembly division and a paint shop. The electric motors used in the machines were purchased from a small firm in Pittsburgh, Pennsylvania. At the time of this expansion, the National Equipment Corporation severed commercial relations with a large Chicago forge company and acquired the controlling shares of stock in a small forge and foundry works a few miles away from the plant's Dearborn, Michigan, home office.

The sudden expansion created some problems, but operations were relatively smooth. Equipment parts were, however, not perfect fits, and many times newly built equipment had to be taken apart and the nonfitting part either remachined, reground, honed, or otherwise repaired. The engineering department was blamed for most of the defective parts. When supervisory personnel were warned against poorly completed parts, they made the statement that the specifications listed on the design were reproduced. Thus, if the part did not fit, it was entirely an engineering fault. When word got to the design department, the chief design engineer instructed the draftsman or the designer of the parts in question to check the development of the part in the shop so that in case the part was not made according to specifications, the design department would be in the clear. As an upshot of this decision, several serious problems arose in the machine shop. Engineers stopped operators and instructed them to do the work differently. In several instances the engineer who designed the part in question stopped the worker, made him measure the dimensions, and proved to him that he was doing it wrongly. When the worker said that this boss suggested that he do it that way, the engineer called the foreman and told him that although the design indicated that the dimensions should be such and such, the foreman had instructed the worker differently. After this happened, the workers often turned to the engineers when they were around in the shop and in many instances disregarded the instructions given to them by their own foremen.

This system worked until a part common to thirty-eight different machines was designed. During the completion of the part, the chief engineer made production decisions and at times even instructed workers to do the work differently than they were instructed by their foremen. The result was that when the machines were assembled, all thirty-eight had to be taken apart and ultimately the parts turned out to be unusable. The foremen involved shrugged their shoulders; the chief engineer had directed the production of that part, not they.

At the final delivery of the machines in question, it was discovered that the total payment received from the customer was 7% below the costs of production. This was the first loss which the National Equipment Corporation had sustained during its fifteen years of operation. To prevent similar happenings in the future, the management appointed a chief inspector who was to report any shortcomings to the management. At the end of the first week, however, problems developed with the new inspection department. Inspectors stopped operators and rejected parts which deviated a little from the design specification. Employees started to complain because of frequent interruptions, which prevented them from earning incentive pay. Many of the employees complained that they could barely make day rate as a result of inspection. When the inspectors rejected 60% of the parts, the inspection department was placed under the authority of the shop superintendent. Since foremen received ½% of the bonus payment earned by the workers, foremen were antagonistic to the whole idea of inspectors telling them what to do. Now the independence of the inspection department was jeopardized; for when inspectors stated that a part should be rejected, foremen often told the inspectors that the work was satisfactory from their point of view. Thus, many defective parts reached the assembly department and shipments were often returned from the customers. In instances when the products were not rejected, repair and replacement parts were requested from the National Equipment Corporation. The customer companies deducted an unusually large sum of money for the labor cost incurred by having their own repair and maintenance personnel change the ill-fitting parts.

Since some defective parts continued to be shipped, the company restored the inspection department's independence, and inspectors began to stop operators as usual. Constant arguments between inspectors and supervisors developed, with the result that employees did not quite know who was their "real boss." Disciplinary and other problems have subsequently developed with further detrimental effect on production; both product quality and timely delivery have deteriorated. The latter started to hurt the company's reputation; for in the past the company was considered to be one of the most reliable manufacturers of equipment in every respect.

The scheduling procedure which the company followed in the past was that the sales department consulted the foremen who were involved in the production of the parts and the assembly of the machines in question. The foremen estimated the date at which they could complete the making of the needed parts, and the assembly foreman stated when he would be able to assemble the parts into a machine, provided the parts were available as promised by the machine shop foremen. However, because of the delays resulting from scrap production, none of the departments could fulfill their promises.

To remedy the scheduling difficulty, the sales department decided to employ a new scheduling system based on the estimated labor time. The bid preparation listed the estimated labor time department by department. On the basis of this information, the sales department knew in advance the time required to complete the already existing orders and added as many man-hours of labor to each departmental work load as was listed on the bid sheets. The total number of hours was then deducted from the available weekly working hours per department (that is, 40 man-hours of labor × 17 paint shop workers = 680). When the hours were translated into days and calender dates, the sales department made a commitment without consulting the production departments. To make certain that the various departments involved could complete the job, the sales department issued production orders directly to the departmental foremen. Thus, in addition to the constant arguments with inspectors, friction between sales and production developed. Sales insisted that production must be completed on a given date, and production stated that they had not been consulted and that it could not be done. The engineering estimates and industrial engineering's synthetic time study procedures indicated the time required on the bid sheets. The bid sheets were prepared by the engineering, process engineering, and industrial engineering departments. Finally, the cost department determined the bid price, to which 20% profit was added. Since in the past, with the exception of the recently closed-out contract, most jobs earned nearly 20% profit, it was assumed that the labor time (labor cost) estimates were sufficiently accurate to base delivery commitments on them. Thus, the sales department accused the production departments of inefficiency.

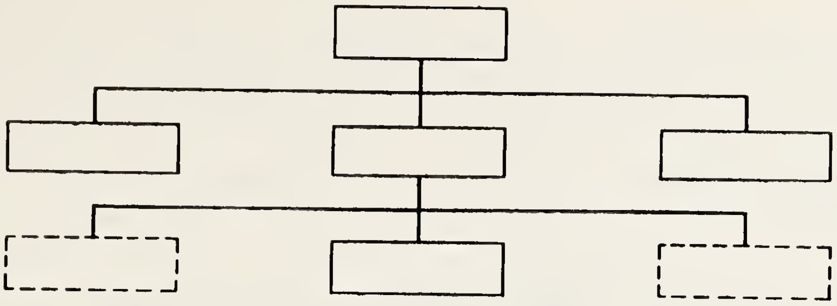
The superintendent was usually a mediator and tried to please all the departments involved. However, he never reprimanded his own men. He always promised the sales department prompt delivery and produced the item with overtime work rather than break his word.

Because the plant superintendent was a nice fellow, little friction lasted longer than the initial argument. Thereafter the situation was ironed out by some special arrangement made by the superintendent. The fact that such special favors were costly apparently did not enter the mind of the superintendent until at the end of the fiscal year the company ended up with a considerable financial loss.

Because of the importance of the above-described case it was brought to the attention of the company's president. He immediately recognized the roots of the problem and decided to make the necessary reorganization. For this reason he called in his private secretary and dictated an organization manual in which he laid down the relationship between people, designated authorities and responsibilities, and established a production planning department which was placed under the authority of the plant superintendent. In the foreword of this manual he stated that "In this manufacturing company, it is essential that engineering and production departments cooperate with one another, but it is essential to know where the authority of the one stops and the responsibility of the other begins."

Questions. The student should analyze the problems involved in this case by recourse to the standard approach outlined at the outset.

1. What are the symptoms that the company is in difficulty?
2. What are the causes of these symptoms?
3. Are these natural causes or do they result from misapplication or misunderstanding of certain management principles?
4. If a violation of organization and management principles is involved and you are able to point out places where such violations appear, indicate the principle itself and the violation thereof.
5. Draw up the organization chart based on the information given in the case description. To facilitate the drawing up of a picture which can show line-and-staff relationships, please use boxes drawn with broken lines to indicate staff departments and the boxes with solid lines to indicate line departments with line authority. Thus, the organization chart should be as shown in the accompanying illustration.



6. Draw up a suggested (an improved) organization chart and indicate the relationship between man and man as far as the proposed organization is concerned.

7. If the organization as you have charted it does not eliminate the causes listed in the case analysis (Questions 2 and 3), then give here a list of suggestions which would lead to orderly and profitable plant operations.

8. Describe the personal shortcomings of executives which might have led to the situation which caused the company to end up with a substantial loss.

chapter 4

Production Management

Because this book restricts the meaning of production management to activities directly concerned with the making of goods, many fringe issues must be left out. Nevertheless, every activity necessary or relevant to setting up and implementing production plans is discussed. By their very nature these managerial activities are inextricably interlaced and constitute a system. Even though Chapters 1 and 3 gave adequate information for a general understanding, the system behind modern production warrants further study. This chapter is concerned, therefore, with the interrelatedness of the various parts with one another and with the production system as a whole.

PRODUCTION ORGANIZATION

Management connotes both "activity" and "people." We are dealing with the diverse yet related activities of members of management as a group. Although sales and financial matters, personnel and industrial relations problems are in many important respects interlaced with the production problem, only some segments of those activities will be treated here, and then only when they serve the production function directly.

Whereas sales forecasting would ordinarily fall under marketing management, production tends to be interested in sales forecast figures as bases of scheduling considerations in the large-scale production of standard items. Wage incentives will also be discussed as an integral part of production scheduling in job shop operations; yet the development of wage incentive systems is an industrial engineering function and the administration of the program is usually a function of the personnel department. Labor relations per se do not concern us as a distinct managerial function, yet they do interest production management in that in most production situations one deals with organized labor. So it is that the limitations and restrictions imposed upon operating management by the labor contract are of considerable interest, particularly in the area of execution and implementation of production plans. As we have said, only those aspects of the various managerial activities which are in some manner relevant to production as a function must be considered here as part of the production system.

Although in the strictest sense the worker is a part of the production system, our considerations preclude the labor factor merely because we are concerned here with the "management" of production. Nevertheless, the production factor, labor, is dealt with in connection with supervisory function. The supervisor above the labor factor is a part of management and will be subject to analysis in light of the production system. Obviously, the supervisor as the boss of the employees constitutes a vital part of the production system inasmuch as the supervisory group is the last link between management and actual performance. Management makes plans and implements decisions; the worker carries out the operation in a manner required by his superior. Each worker is in contact with his immediate supervisor, who directs him in production by telling him what to do, how to do it, and when to start on any given assignment. Because managerial work, particularly in large companies, is quite time consuming, a large number of management personnel, in both line and in staff capacities, are needed to set up plans and work out the details of implementing this predetermined action.

Just as energy holds atoms together to form molecules, so responsibility acts as the binding agent and holds together a group of men in managerial positions to form the industrial organization. The men then work as a team and run the operations of an industrial enterprise with a division of responsibilities. The production organization also includes those who perform vital managerial work but do not concern themselves with operations per se. No matter whether he is a staff or a line member of management, as long as each individual performs his specific task to the extent of his responsibility, efficient production will result. Inefficiency is nearly impossible if all related parts of the production organization are properly coordinated.

While the management organization is composed of line and staff members, line executives—from president down to operating management—are responsible for the outcome of production. This, however, does not imply that every member of management worries about every aspect of production. On the contrary, by the division of responsibility, planning, like the line end of management, is divided among a large number of specialists. Finally, these plans are tallied and unified and turned over to line management. The latter's share of responsibility is to make the plans a reality and account for the results in both the qualitative and quantitative senses. Apparently, then, the modern industrial organization is strengthened by the addition of a large number of staff specialists, who through their planning and advisory services can provide a better basis for decisions. But the staff man is not responsible for the ensuing results.

Although the contribution of each member of the complex management team is relatively small, the cumulative effect of the team effort is tremendous as far as the industrial organization as a whole is concerned. The vast number of production problems large or small are pinpointed, analyzed, and solved by many individuals whose responsibility is confined to certain problems only. Because of the aggregate knowledge which results from this diffusion of responsibility on the one hand and a subsequent coordination of effort on the other hand, there is a great strength in group planning and action. But, of course, the total result is largely dependent upon the individual parts which make up the whole and how well these integral parts are pieced together. While voluntary pooling is the best way to contribute to the total effort of the organization, it becomes a cardinal function of line management to create a harmonious whole out of the independent intellectual efforts. This is referred to as coordination.

Production is the final result of action. Action, in turn, is bound to be predicated upon a plan. The general complexity of industrial problems necessitates joint effort on the part of planner and executor. Accordingly, modern production is teamwork coordinated by the production executive. When specific knowledge of a large number of specialists is coordinated, the combined knowledge is obviously considerably greater than could be had by any single individual. This is the reason why in modern production few production executives can pride themselves on being jacks of all trades; as a matter of fact, their acquired skills tend to fade away as they rise to higher and higher positions of responsibility. In turn, of course, the same executives acquire another vital quality which becomes of paramount importance: leadership.

The production executive is, then, primarily a chief coordinator of men with diverse production talents rather than a production expert, even though his overall comprehension and understanding of production details may be surprisingly high. From the company's point of view, a proper job is done when the executive creates a smoothly functioning team out of individuals possessing highly specialized "intellectual" skills. Today, one must be surrounded by capable men to become a successful production executive. When a group of truly capable men is brought together and teamed up, the executive must reconcile and integrate the many differences in these people. It is one of the most important tasks of a production executive to coordinate everyone's ideas as to how production should be carried out. Maximum individual effort in cooperation with others is the key to production efficiency in a successfully operating industrial organization.

THE PRODUCTION SYSTEM

The high degree of managerial specialization and the coordination of specialized managerial efforts characterizes production in large enterprises. Despite the seemingly independent efforts expended on various projects by staff members of management, in reality no one operates independently in a well-functioning organization because every single managerial activity is somehow related to another. Therefore, if one of the contributing activities is deficient, it is likely that the success of production as a whole will be affected by it.

It is essential, therefore, to assign specific planning activities to engineers, industrial engineers, and production control men and to assign strictly confined supervisory responsibilities to line men. To avoid possible disharmony, it is essential to avoid overlapping assignments of responsibility and to prevent men from working at cross-purposes. It is essential to distribute work among the various members of the management team in such a manner that the resulting production is as efficient as possible.

Since specialists work on certain highly specific aspects of the planning process, the chances are that the component parts of the overall plan are of a very high standard and considerably better than if they had been developed by supervisory personnel on a part-time basis. In order to combine the partial plans into a satisfactory overall plan, a coordinating agency with the responsibility for bringing together the efforts of the various contributing departments must be set up. This agency is the production control department, though it may be called by some other name.

While the production control department performs certain duties of its own, these activities are dependent largely on information which is developed and prepared elsewhere in the organization. Thus, the information must first be gathered for the purpose of further planning. The planning process is a step-by-step process in large companies, where no one performs the planning as a whole. This is very different from planning in a small production organization, where such a degree of separation of various activities relevant to planning does not exist.

Just as the brain and the nervous system exercise control over the proper functioning of the human body so, in any large company where a production control department exists, all activities relevant to planning the flow of production are coordinated into an overall plan by that department. This kind of coordination is different from the effort of the production executive who coordinates the efforts of the various individuals to prevent any one member of the organization from working at cross-purposes with another. The coordination achieved by the production control department is incidental to the planning process. What really happens is this. The production control people set up plans which will subsequently control the various production activities. Since they do not have all the information at their fingertips, it is essential to turn for the necessary information to other departments, and ultimately they will coordinate the efforts of several independently working planning units.

Functional separation of the various managerial duties would, in absence of a coordinating agency, easily counterbalance the benefits of specialization and result in disharmonious action. If control over the independently working planning department is lost, results will fall short of expectation. The organization, like a living organism, must function both in parts and as a whole. This is particularly true where the planning organization is concerned. Alone each segment of the planning organization is worthless; taken together, the segments are an invaluable force.

Figure 4-1 illustrates the organizational interrelatedness of the various parts, namely, process and methods planning—production planning—execution. It is clear that the various members of the production organization—from the overall head down to the shop foreman, from the technically trained engineers to the production planning department, from the sales forecaster to the inventory control man—depend on one another.

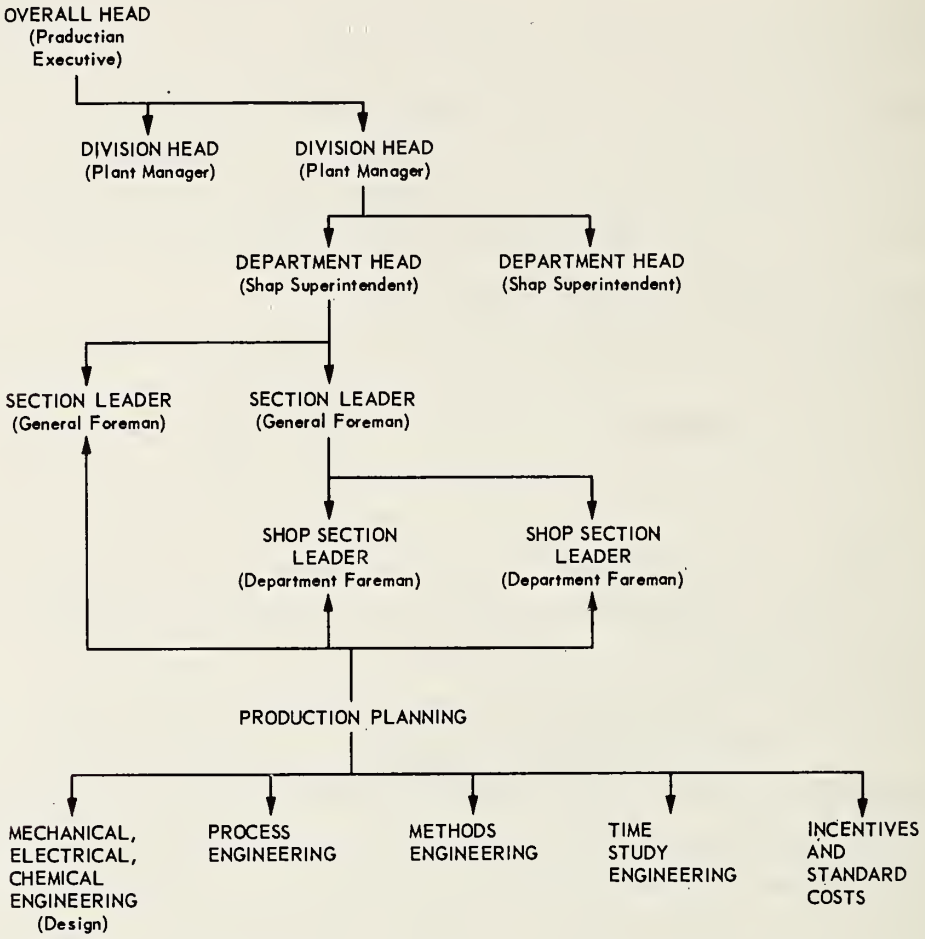


FIG. 4-1. Planning the physical facilities and the work environment.

In the production cycle, engineering planning is chronologically the first inasmuch as the product is conceived in this department, at least on paper. Here too all the technical plans are formulated. Depending on the industry, a chemical, metallurgical, mechanical, or electrical engineering background is needed. At times, however, plain production engineering skill or training is fully adequate, provided it is coupled with some practical experience in the field in question.

After the well-formulated technical plans are ready, and have possibly been complemented by plant layout arrangements, it is essential to set up additional plans to put the wheels of production in motion. In the case of operations where the production line technique is applicable, simply a go-ahead sign must be given, along with a specification of the quantity to be produced. In the case of job-lot operations where a functional plant layout exists, it is essential to establish feasible routes through which the product is to pass at predetermined times. Though time seems to be the primary element in scheduling, cost is an equally important factor.

It is not enough to set the wheels of production in motion; serious efforts must be made to control flow of production in the plant and meet predetermined schedules. Whereas production people in positions of responsibility and line authority are actually accountable for meeting production requirements, the staff counterpart, the expeditor, has a similar though less crucial concern for production. The expeditor is there to make sure that everything flows in as orderly a manner as the schedule demands. While line people control actual execution by control over subordinates, the expeditor checks that the plan is being followed.

Obviously, unless line personnel follow the predetermined plans, effective operations are impossible. Therefore, production plans must be transmitted in such a form that supervisory personnel can understand them without trouble. At times, precise plans are turned over to supervisors; at other times, production plans do not map out every detail. In the latter case supervisors are free to arrange the flow of production as they think advisable, but they must still stay within the confines of the overall plan.

Even though these plans are frequently quite specific, the planning department is there to facilitate the work of supervisors by relieving them of major parts of planning duties. Judging a man's work in supervisory positions, one comes to the conclusion that a very large part of the daily work consists of setting up plans and mapping out the various possibilities which will make execution possible. Particularly because supervisory personnel are not as familiar with planning techniques as trained planners, it is certain that the planning department develops better plans than supervisory personnel could. For this reason, in many companies every detail is developed in the planning department. The plans are followed by supervisory personnel because they realize the importance of centralized planning. While greater efficiency results from competent planning effort, at times this help is resented because the plan sets rigid time limits within which production must be performed. Because a greater degree of regimentation is required if every minute of the workday is carefully mapped out, a greater supervisory effort to meet the schedules is required. The plans are certainly better, since the production planning group works with scientifically determined data and can develop production schedules considerably better than supervisors who tend to improvise all the time and make plans on the spur of the moment.

Because of functional separation, supervisory management is relieved of the most time-consuming planning duties. Supervisory time has thus been increased and more time can be devoted to direct control and direction of subordinate employees. As a result, employee idleness, defective or wasteful production, and many other undesirable features of production are minimized, if not fully eliminated. Under careful planning the most urgent jobs can be completed first. This is not necessarily so when scheduling is in the hands of busy supervisors who, when under pressure, tend to forget the proper allocation of departmental work loads. As a result, overtime work is reduced, cost of production is under greater control, and delivery promises are more easily met. Moreover, an orderly flow of production is possible despite unavoidable interruptions and back-trackings.

These production plans are developed in an office. Centralized production planning is, in a sense, a remote-control method. It follows that unless a great deal of technical information is available, the planning department cannot set up plans to control the flow of production in a production shop located miles away. It is imperative, therefore, to have an excellent communication system. The information necessary for planning must be gathered; then it must be organized and arranged. In this sense planning is akin to a jigsaw puzzle, because all relevant information must be placed in a given order.

Here the explanation of the production planning procedure has been oversimplified. In practice, the technical details are worked out by various engineers. Engineers collect, develop, or produce information which falls within their specific jurisdictions. As far as the production planning department is concerned the engineering data thus developed are essentially an incomplete plan. All these partial plans when they are properly put together constitute the overall production plan.

The fact that partial plans are synchronized into an overall plan indicates that each department specializes in the development of a certain kind of information and a certain kind of fragmentary plan. When the efforts of each department are coordinated through the production control department, the partial plans developed by every technical department are brought together to serve the common goal. Because of this earlier-mentioned coordinative element involved in production planning work, the production control department is classified as a "coordinative staff" department.

It should be pointed out, however, that there is a great deal more to production control work than gathering and summarizing information. The latter is only preliminary to the more important work of systematic arrangement of information in line with important considerations such as delivery commitments, availability of raw materials, and cost factors. Furthermore, dovetailing of related production departmental activities must be undertaken. Whether an electronic computer is used to take care of the routine work involved or members of the production planning department work on the plans with charts and graphs is, of course, immaterial. Nevertheless, it should be remembered that facts must be logically and systematically arranged. If an electronic computer is used, it must be programmed for the purpose. Operation times, departmental capacities, economic lot quantities, operation sequences, and equipment versatilities must be reconciled with consumer specifications of quality, time of delivery, and production volume.

It is essential that plans are feasible and can actually be accomplished in the various production departments. If the data used in the planning process reflect the true situation, then the plan mapping out the course of action is bound to lead to efficient production; barring, of course, incompetent supervision.

The plan or plans which we have mentioned may take different forms. They may be embodied in route sheets, production schedules, job cards, etc. These plans tell foremen what should be done and when and with what equipment it should be done. This flow of information from engineer and sales forcaster to planner and from production control to supervisors is reiterated in Figs. 4-2 and 4-3, respectively.

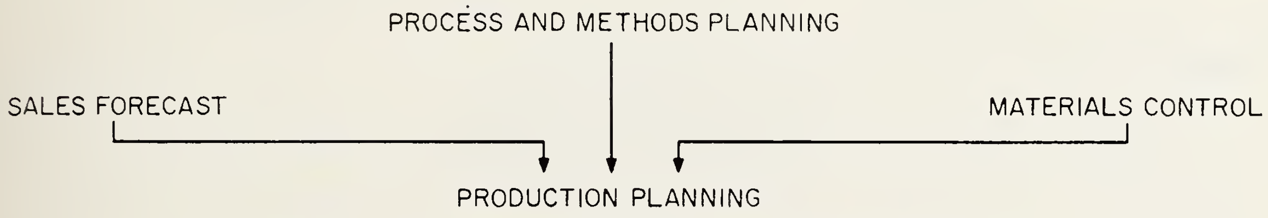
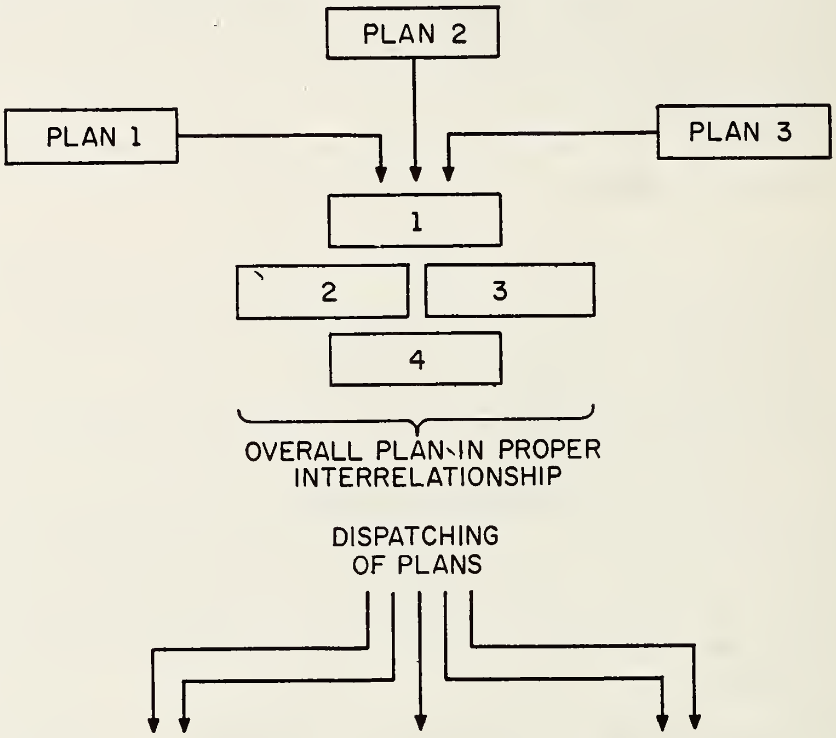


FIG. 4-2. Information flow to production planning.

In the absence of a production planning department, one of the higher ranking executives develops the production plan on the basis of discussion of inherent problems with the sales department and the line foremen. In this case the planning function is not fully separated from the executive and supervisory functions.

When production plans are made as indicated in Fig. 4-3, the main function of supervisory personnel is to follow the plans as closely as possible and report progress to the planning department. The main obligation is then to make things happen in accordance with the plan while, at the same time, putting quality into the product, controlling employee performance, and keeping down the costs of production. The foremen who are overloaded with planning and other duties will have little time for supervision. Therefore, unsolved problems tend to mount. Because no one can be made accountable for errors, rejects, and delays except the supervisor, unless supervisory personnel are accorded sufficient time to do a good job of supervision, it is difficult to expect them to assume responsibility for the performance of the subordinates.

Even though carefully developed production plans put an added burden —though different from planning—on the shoulders of first-line supervisors, their work is greatly facilitated. It is true they have to work constantly against a deadline, but they can get things done because they are relieved of the planning, which would otherwise take much of their time and tax their capabilities too heavily. Without this duty things are much easier for them, despite the apparent difficulty of complaining employees. Evidently, workers prefer plants where supervisors are busy and an easy-going atmosphere prevails. Since employees do not like pressure—and the system described above puts a great deal of pressure on everybody who is concerned with production —strict supervision is not a popular phenomenon in most production shops. In a sense supervisors tend to become shock absorbers and carry the burden of the added production efficiency.



THE PLANNING AND DISPATCHING FUNCTIONS

Supervisory personnel always receive only that segment of the plan which falls under the jurisdiction of given departments (distributed according to responsibility)

Fig. 4-3. Synchronizing and unifying partial plans 1, 2, and 3 into an overall plan "4."

Where production planning is separated from direction and control of performance, execution involves 1) receipt and study of the plan, 2) selection of the employee or employees capable of performing specific tasks, and finally, 3) direction, control, and coordination of the work of subordinates. The activities listed under point 3 mean simply a verbal communication between foreman and subordinates about what to do, how to do it, and when to start or finish it as well as a subsequent follow-up to see that the work thus organized and allocated is properly performed.

PROCESS AND METHODS PLANNING

It is often difficult to determine where production begins and other related activities end. Thus, both sales forecasting and design engineering are done in the interest of production, but they are not production in the sense that they actively contribute to the making of goods. For the sake of demarcation, it should be assumed that any activity prior to putting the wheels of production into motion, but after the production design has been completed, is production. In addition, auxiliary activities such as inventory control and tools control cannot be neglected, because production cannot be carried out without them.

Design serves primarily as a means of visualizing the product. One thinks of design usually as a picture or as some sort of a chemical formula, but it can take many other forms. Nevertheless, one prerequisite is that an adequate blueprint on which to base production should be available. At this stage, every product is merely an idea, even though technical and production feasibility have already been tested.

It is the function of engineering as well as production planning and supervision to make the idea embodied in the design a reality and a tangible good. In the interest of a logical development, let us retard our progress a bit and explain briefly the production aspects of the design; afterward we can pursue our main interest and focus undivided attention on production: how it is planned and how the decisions are implemented and accomplished. The product conceived on paper must be tested as to whether it can be produced in an economical manner, always keeping consumer requirements in mind. This may be done in the laboratory through experiments, engineering calculations, manipulations of chemical formulas, making samples, etc.

Regardless of what form the design takes, it must be technically adequate to visualize the product in question and to start manufacturing on that basis. While a picture is preferable to a lengthy description, a picture alone is usually insufficient. To build a house, the design must contain weights, measurements, dimensions, stresses, and many other pertinent data. To produce factory-made goods, it is equally essential that the design should detail all essential information as to the materials, measurements, and tools to be used. While the tools do not have to be described in detail, some desirable method of production as seen by the designer is helpful. In other words, everything that is necessary to start production must be on that piece of paper called the design. Of course, it is not important that every layman be able to read the blueprint or understand the implications of the design, but experts in the field should be able to interpret it correctly and visualize the method by which production can take place.

The design is the basis for process and methods planning. Once a design is available, it is possible to set up plans for production. The question that then arises is to whom the design should go next. The most likely department is process engineering. Its function is to determine a feasible production process for the item in question. To accomplish the above task, two steps are necessary: the breakdown of the product into component parts and the determination of a suitable production process for each part.

The engineering background needed depends largely on the nature of the product. To design an efficient production process in coal mining or mining of ferrous metals or any other mineral deposits, mining engineering background is needed. The extraction of lumber would ordinarily presuppose a forest engineering background. Production of chemicals, both heavy and light, implies availability of a background in chemical engineering, in addition to actual production experience. Similarly, the development of a production process for the building of a bridge will require appropriate engineering skills. A bridge would involve many different types of processing activities dealing with specific problems in the fields of civil, mechanical, and architectural engineering. Therefore, the processing problems would fall into several engineering areas and the possible problems should be solved on paper before starting to build. Every step is determined in advance before moving a beam or a stone. This is the task of the process engineer.

This brief résumé indicates that process designing requires men with 1) technical knowledge, 2) production knowledge, 3) familiarity with production equipment and capacity requirements under different production conditions, 4) cost consciousness, and 5) other knowledge appropriate to production of the product in question. It is not necessary to discuss everything that a process engineer must know to be able to determine a good production process, but it is worthwhile to point out that process designing is a highly specific task that requires extensive technical and production training in the field and practical know-how. While here a superficial explanation is adequate, the specific qualifications of process engineers will be stated later on.

PRODUCT DESIGN

As previously indicated, in order to produce something, a design drawing or facsimile must be available. It must show every feature of the product in such a manner that production can begin on the basis of the blueprint. The design drawing should conceivably be in a form more detailed than a drawing acceptable by the Patent Office of the United States Department of Commerce.[1] The design drawing is the basis of all sorts of planning purposes.

On the basis of the design, everybody concerned with production can visualize the product or parts thereof. This does not imply, however, that laymen also can follow the information supplied by the drawing. This would be particularly true in the chemical industry where, instead of a picture, a series of chemical formulas serves the same purpose as the design generally used in the metalworking trade. In addition to the shape and form, the design will indicate qualitative specifications, which might refer to the type of raw material, the exact dimensions, and the permissible deviation from them (otherwise called "tolerance requirements") and any other information necessary to set up technical plans to start production. Generally speaking, the line supervisors can read the blueprint. This is not always essential, although it is difficult to imagine that a foreman, who should instruct and direct the operator as to how to do the work and check on the employee's performance would not know how to interpret the design drawing and the information which it contains.

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[1] A patent is the "right" excluding others from making, using, or selling an invention during a term of years; in the United States this term is 17 years.

Production efficiency is related to the design inasmuch as the latter determines the method of processing. Therefore, the design should lend itself costwise to economical production. This means that while the design cannot neglect the interest of the consumer, it must be such that the interest of the producer is fully served. Regardless of the excellence of the design both in the functional and in the marketing sense, unless it can be built at a cost commensurate with the consumer's pocketbook, the design is unrealistic.

At present our interest confines itself to the production design. This simply says that the form, shape, and composition of a product-to-be must be such that it can be processed easily, cheaply, and with the least possible disturbance. The fewer the number of operations, the fewer the necessary machines and workers, the fewer are the problems to be solved. The design frequently undergoes minor changes even after production has begun. These changes become necessary because during operations it will be found out whether the production of an item in its original design causes overhigh costs of production. It is doubtless true that the successful application of the production design principle makes production of any item commercially profitable.

PROCESS ENGINEERING

Planning considerations center around the practicability of the design. While our considerations preclude technical problems per se, it is essential to start with a borderline problem falling between engineering as a technical skill and industrial engineering as a semitechnical staff activity. Process engineering would ordinarily require a skill learned in an engineering school (mechanical, electrical, chemical, etc.) and production experience combined with industrial engineering know-how. At any rate, process engineering as a special branch of engineering is so closely related to the production planning problems that some degree of discussion is warranted.

Although process engineers are often confused with industrial engineers, the fact is that successful process engineering requires a thorough knowledge of engineering disciplines. The process engineer's function is a starting point because every activity is built upon the process which he designs. The process engineer determines what should be done to the raw materials, with which machine, and in which particular sequence. The plan is written on a sheet of paper which assumes the name "process sheet." Thereafter the process sheet becomes the bible for further planning purposes.

The developing of a process sheet is preceded by the development of a bill of materials. The parts list, which is another name for it, is based on the design and the information it contains. It is merely a list of the component parts of the item as found on a design drawing. The list of materials can be a summary of the various chemical components which make up a chemical product. The bill of materials is subsequently analyzed in the light of production. On the bill those items which the company decides to produce will be separated from items to be purchased. For planning purposes only those items which the company decides to produce will be subjected to a process analysis and will consequently be process-sheeted. In other words, a production process is developed only for those items which are contemplated for production. Which items an industrial enterprise will produce and which ones it will farm out to other companies depends on many considerations. Usually a company will make an item if equipment is available or if the company has a sufficient amount of excess capacity and can fit its schedule into the overall production plan. A company might even then produce an item when it would be costwise more economical to farm it out. But, as we have said, there are many considerations which might enter that decision.

The process sheet and the bill of materials are usually in writing. But it is not unusual, particularly in small companies, that there is no bill of materials or process sheet in existence. Decisions are then made on the basis of a memorized parts list and process sheet. In large companies this kind of system is unworkable, because so many people are interested in the information that it must circulate freely among departments. For this reason, formalized bills of materials and process sheets are necessary where the planning process is divided among a number of related staff departments such as industrial engineering, production control, and inventory control.

INDUSTRIAL ENGINEERING

Most of the preliminary work essential to orderly production is performed by process engineers and industrial engineers. The bill of material and the process sheet pass from one hand to another. They go to the industrial engineering department on the one hand and to the production control department on the other.

When the process sheet arrives in the industrial engineering department, several planning activities begin. Either the process design is analyzed as to the propriety of the method or the individual operations are time-studied and standardized. If the company operates under a wage incentive system, the time standards thus established may be modified in the light of an adequate incentive allowance. At any rate any further planning before the start of production is based on the process sheet.

What then precisely is done by industrial engineers? In a highly oversimplified fashion, the industrial engineering department is the "cost reduction department," and it will look at the predetermined production process with cost reduction in mind. Its function is to make certain that the item in question is produced in the best possible manner.

The term "industrial engineer" implies various semitechnical activities. This name replaces the original title "efficiency expert," a vaguely defined activity related to production. The change of name reflects the changes in the function itself. It has become expanded, then subdivided into a number of specialties, such as methods engineering, time and motion study engineering, plant layout and materials-handling engineering, and wage incentives and standard costs engineering. According to the American Institute of Industrial Engineers, the industrial engineer is concerned with the design, improvement, and installation of an integrated system of men, materials, and equipment. It draws upon specialized knowledge and skills in the mathematical, physical, and social sciences—together with the principles and methods of engineering analysis and design—to specify, predict, and evaluate the results to be obtained from such systems.

The difficult challenge of maintaining adequate profit margins in face of extreme competition requires management to shave controllable expenses in every possible way. Thus, the industrial engineer is constantly on the lookout for better ways and means of doing the work, of facilitating production, and of establishing partly technical, partly nontechnical production systems in the interest of efficiency.

The word "engineering" is somewhat out of place here. These activities require little knowledge of engineering in the ordinary sense of the word. The name is apparently derived from the fact that people who occupied themselves with these kinds of problems were engineers. The industrial engineer encounters technical problems only at the periphery of his work.

Although the industrial engineer is not concerned with social science, he cannot avoid establishing contact with that field inasmuch as production, even in a highly mechanized shop, depends largely upon people. Since the technical problems are interlaced with human problems, it becomes a part of industrial engineering to resolve the equation between the technical and the human problems as they arise in industrial situations. The fact that behind every machine and tool stands a human being emphasizes the relationship between technology and "humanology." If production processes are technically standardized, the human being and his performance must also be brought in line with these standardized conditions.

To minimize or eliminate work fluctuations due to the human factor, attempts are constantly being made to make the human being subservient to machinery. Where possible, the human factor is being eliminated, as illustrated by the general progress of automation. But until automation replaces the human being, industrial engineering—with the task of fitting the worker into a mechanized environment—will remain one of the essential ingredients of effective and costwise favorable production. Thus, industrial engineers solve technical problems with due regard to the human factor of production.

Despite concentrated automation efforts, industry must reconcile itself to the fact that the human being cannot be eliminated from the scene. Therefore, industrial engineers must, by necessity, be concerned with fitting manpower into production. In dovetailing machine performance with human work the emphasis is on the latter. While technical problems can be calculated and resolved, the magnitude of the human problem depends on many influences which not infrequently fall outside production. For this reason, it is difficult to determine the standard amount of time it should take to perform a given repetitive task. It is equally complicated to establish an output quota which can reasonably be expected of employees on given jobs. This difficulty originates primarily in the basic differences between people in terms of skill, mentality, diligence, perseverance, and so on. Since workers are not machines, in determining performance requirements it is essential to assume "normal" or "average" workers with "normal" skill on the one hand and "normal" working conditions and "normal" work pace on the other. While machines can perform the work on the very first workpiece in the same amount of time as on the last piece, human performance will fluctuate because of fatigue as well as because of the differences between people. It is this fluctuation in performance which must be eliminated or solved somehow in order to enable the production planning group to set up production schedules with some degree of accuracy. This is one of the many important relationships between industrial engineering and production control work.

In cases where production planning has to cope with human situations, it is essential to consider both the technical conditions and the human factors. It is essential to know among other things that workers seldom produce a good day's work. They do not exert themselves, unless they have an incentive to work harder than they feel like working. Experiments tend to indicate that workers withhold nearly 50% of their productive efforts. Based on such assumptions, the task of the industrial engineer is to develop incentive systems capable of inducing workers to perform up to their productive capabilities. While time and motion studies are able to reveal the minimum (and maximum) output per hour, it is another matter whether this quantity can be legitimately obtained. Therefore, wage incentives must often correlate basic environmental, physical, and psychological factors with time study data.

Barring the possibility of constantly moving conveyorized production lines, regimentation often becomes necessary to ensure efficiency of operations. Thus, industrial engineers work on methods which aim to reduce the necessity of slave-driving supervisory techniques. Obviously, one must find the middle road where the dignity of man and the production objectives in terms of quantity can be reconciled with one another.

While human beings become tired and need rest, the question that arises is when workers become tired enough to deserve a rest and how the rest period should be arranged to bring about the most favorable results in productivity. To determine plans of this nature, it is no longer sufficient that industrial engineers remain in the production domain proper; instead, they must venture into the field of physiology and investigate human physical needs. Thus, this work requires some understanding of the social sciences and, particularly, the relationship between them and technology.

Whereas the efforts of industrial engineers are concentrated on improvement of productivity through a better integration of men, machines, and work environment, the improvement of materials and products is frequently a by-product. In general, industrial engineering explores the possibility of using newer and better methods, which in turn can lead to products of better quality, the use of cheaper yet better raw materials and product designs. A suggestion to change the design in order to enable installation of a better production process can lead not only to cost reduction but also to improvement in the product.

The basis of industrial engineering work is research. Different kinds of data must be collected and evaluated in order to develop systems. Industrial engineers usually make sample studies and then devise mathematical formulas to make use of the collected information in some logical manner and to arrive at conclusions necessary to set up an effective production system. A great deal of industrial engineering analysis is concerned with the better arrangement of machinery and materials-handling devices so that the motion pattern involved in the job is simplified and ultimately a high rate of production is achieved with the least amount of effort and time expended. Minimum effort means less fatigue. The smaller the residual fatigue, the greater the resulting performance and the better the quality of workmanship. The study of the best method and the minimization of effort constitute a significant part of the research undertaken by industrial engineers in the interest of standardization and uniformity of human performance.

However, the industrial engineer goes beyond the individual worker and his efforts. The motion analysis explores the whole production process in which the man's job is only a part. The analysis of the individual work station may be merely preliminary to an overall analysis whereby the relationship of one work station to the rest is established. Yet performance analysis may ultimately contribute to a further subdivision of work into faster and simpler motions. This division and improvement of individual work may also be intimately related to the conveyor system. If individual jobs are carefully timed and each job is synchronized with all others, a constantly moving conveyor can be installed to set the pace and, by its very nature, reduce the necessity for supervisory control. Thus the control of work pace will be transferred largely to the pace-setting movements of the conveyor.

In conclusion it is worthwhile to emphasize that the primary function of industrial engineering remains in the general area of worker and machine relationships and work output and cost relationships. Obviously, its most important function lies in the development of plans capable of contributing to a costwise favorable production. In other words, the function of industrial engineering is to furnish information on the basis of which a relatively continuous flow of production results, a better arrangement of plant facilities can be made, and the various elements of production can be synchronized. To accomplish all these, the arrangement of physical facilities, the determination of time and performance standards, and the development of appropriate systems is required. The efforts of industrial engineers coupled with production planning will assure that production activities are not chaotic, but orderly.

PRODUCTION PLANNING

To avoid future repetition, present discussion will be confined to a few generalizations as to the work performed by production planning. The function, as will be seen, may be performed by several people specializing in certain phases of the production planning work or by one individual. A decentralization of production control duties is often practiced by small companies whereby certain phases of the production planning work are done by various line people of high or low rank on a part-time basis. The possible arrangements are as many as there are industrial practices. We shall here confine ourselves to a production system so set up that the production control function is a separate and distinct part and a particular group of people, the production planning group, occupy themselves with production control work.

The function of production planning is to develop feasible plans for action in the shop. The department takes over where engineering planning leaves off. The overall plan divides the work load between the various departments and machines, in addition to establishing a relatively smooth flow of production. Hence, production planning is instrumental in 1) achieving low-cost operations, 2) controlling and maintaining delivery commitments, 3) achieving maximum utilization of plant facilities, and 4) discovering eventual production bottlenecks far ahead of their possible development and thereby giving adequate time to prevent their development.

The production planning function also lends itself to specialization. While it is not necessary to separate the various aspects of production planning, it is practical to do so in large companies. The reason is that each production planning subfunction is sufficiently complicated to keep at least one specialist busy. On the other hand, in small companies a single individual may be capable of handling most or all the production planning functions.

Routing and Scheduling Functions

The first two aspects of the planning function are routing and scheduling. The two are so closely related that it is frequently difficult to say where routing ends and scheduling begins. For the present purpose, let us assume that the main function of the "router" consists of gathering all the necessary information, both technical and nontechnical, to route the product in question through the shop. In order to accomplish this, the employee designated as router turns to various technical departments to get machine data, processing methods, time study data, etc. The above information, when organized and written down on a route sheet, becomes the basis of production scheduling. The route sheet is then the basis of the scheduler's work. The latter calculates (with the time studies prepared for him conveniently on the route sheet) the time occupancy of a machine and thereby develops a certain production schedule.

While an oversimplified version is given here, one should not lose sight of the fact that these functions are considerably more complicated. Particularly in job shops will production scheduling and routing functions be difficult. In intermittent production different items are made and each product must make use of the same equipment. Thus, a waiting-line system must be worked out and that item must always be scheduled on the machine which is most important from the point of view of delivery or production sequence. Routing and scheduling therefore require up-to-date information which may be kept on charts, planning boards, or records. At any rate, these must indicate with clarity the current state and progress of each item made in the production shop.

Indicating progress is one of the many functions of charts; another is to indicate which equipment is available and how long the machine is free to receive new job assignments. Since effective production implies the use of the costwise most economical equipment, it is essential to relate not only capacity availabilities with jobs, but also the cost with which each machine in question can accomplish the particular assignment. While the latter is a routing function, it is apparent how closely it is interlaced with scheduling, which is the actual planning function. The accuracy of the production plan will determine whether the cost of production will turn out to be high or low. Of course, this in itself, no matter how excellently planned, does not guarantee efficient operations unless the supervisory personnel are able to carry out the work load assigned to them in accordance with the production plans.

Costwise best path selection, one of the many facets of the routing function, is important primarily in intermittent production. In continuous production, this part of the planning function is less important because the plant layout itself is usually so designed that the path is built into the production line. The scheduling function is important, however, in both the continuous and intermittent production. In continuous production, any mistake on the part of the scheduler can idle not only one or two pieces of equipment but the whole production line.

DISPATCHING AND EXPEDITING

The functions of dispatching and expediting follow routing and scheduling. In big business, the production schedule must always be followed up to avoid costly delays and bottlenecks. Yet, the plan of action is still merely a theory. Thus, even the best of plans can fail if the raw materials are not available as required by the schedule, if tools are not ready when needed, or if some unforseen happening holds up production. The schedule is the production plan all right, but it serves the purpose of production only if it is a realistic plan. Therefore, it is the task of the dispatcher to check whether all problems related to the flow of production have been satisfactorily solved, that is, tools are available, raw materials are ready and reserved, and blueprints, job cards, and other instructions are ready.

The main function of the dispatcher is, then, to see to it that the implementation of plans is properly carried out and that the plan is feasible not only on paper but also in practice. If minor discrepancies between planned action and current circumstances arise, it is the task of the dispatcher to make the necessary adjustments. The dispatcher must occasionally reschedule work in light of current happenings. Barring drastic changes, the dispatcher prepares everything necessary to start production; and when everything is checked out, he gives the go-ahead sign.

The expeditor deals with production inasmuch as he must see to it that plans are followed and that action conforms to preestablished production schedules. An expeditor is needed in most places because a factory is a busy place. Workers do productive work, the wheels of machines rotate, raw materials and semifinished materials are being transported from place to place, the foremen are walking back and forth directing and controlling the performance of subordinate employees, and so on. Hence it is easy to forget to do something. If the busy foreman forgets to follow the plans established by the planning department, bottlenecks and serious production delays may develop. Loss in production time must always be prevented. And it is the function of the expeditor to remind the foremen all the time what must be done and when it must be accomplished. In this sense the expeditor is similar to the private secretary of a busy top executive. The expeditor remembers everything. Since delays are cumulative in character, if a given operation is not performed at the scheduled time, it is likely that the immediately following operation will also be delayed. Thus a chain reaction can easily develop, which will have serious consequences throughout the shop.

Delays may necessitate overtime work because delivery commitments must usually be adhered to. Overtime work is, of course, more expensive than work performed during the normal work shift. The fact may not be neglected that downtime on machines constitutes a total loss and might be quite serious when the company has a large backlog of orders.

The expeditor can be instrumental in preventing delays by keeping tabs on operations and following up work until the job in question is completed. At times even the expeditor is forced to make last-minute changes in production schedules. This does not imply a complete remapping of production, but merely some adjustments here and there where unforeseen troubles develop.

Generally speaking, the expeditor acts as a watchdog of adherence to plans, not the foremen. This is a very important distinction, and it should be emphasized that expeditors have no authority over foremen. Expeditors merely aid the supervisory group in the maintenance of production schedules. Since their duties are restricted to observation and suggestion, the most that expeditors can accomplish is to remind supervisors what jobs are to be started and finished at certain times. By making sure that everything starts and is completed at predetermined times, expeditors exercise a substantial control over execution of production plans. If everything moves as predetermined by schedules, the chances are that production and delivery will be made without overtime work and pay and with lowest storage and other costs.

This differs from expediting prevalent in the late 1930s. Expediting was used in lieu of the scheduling function. While it fulfilled the scheduling function in some fashion, the arrangement was not very satisfactory. Ordinarily, several expeditors were responsible for certain segments of the whole production program. By putting pressure on supervisors, expeditors succeeded in getting work accomplished, often at the expense of other, more important jobs. Today's expediting merely sees to it that everything moves according to the original schedule. Where orderly scheduling takes place, expeditors are neither biased nor do they attempt to conceal delays for fear that production delays will adversely reflect on the reputation of supervisors. As a result of objectivity, changes and reschedules are quickly and efficiently made. While in the absence of follow-up men the expediting work is a supervisory duty, it is evident that it usually falls short of maximum accomplishment. Surely enough, expeditors would not be necessary if foremen were able to remember everything, but haste and the general turbulance of operations prevent the kind of perfection which we should ordinarily expect from foremen. For this reason, expediting as a function is fully warranted. The by-product of expediting is that the sales office can always keep the customer informed about progress, cancellations can easily be expedited and further work on the contract stopped in the shop, inventory control can be facilitated, and many functions related to production can be accomplished better than would be possible without follow-up men.

Without production planning, control over the flow of production would be extremely difficult, particularly in an intermittent job shop. Obviously then, expediting is somewhat more important in the job shop than in continuous production. Nevertheless, the importance of the expediting function cannot be underestimated in either case. The only difference between its function in job shops and in production-line type operations is that in the first instance expediting is concerned with movement of the material among machines, as opposed to the second case, where expediting assures arrival of raw materials either at the beginning of the production line and at subassembly stations or at feeder assembly stations. Hence, the nature of expediting may differ, but its importance becomes by no means less in any one of the above-mentioned situations.

The dispatching and expediting functions are not necessarily performed in the described manner throughout American industry. The description primarily indicates a desirable method.

EXECUTION

In small enterprises where all decisions are made by the owner and his subordinate management personnel, planning and activating usually go hand in hand. In a production system as described in this chapter, activating follows planning, but what is particularly important is that the activator and the planner are not one and the same person. Engineering or production planning departments determine feasible avenues of action, and the executive branch carries them out. The function of line personnel with authority is to put the plans into practice in the specific manner that planning departments think advisable from the point of view of overall production efficiency. In this way the executors in a production system would be fully relieved of detailed planning duties, barring the planning work as to who is going to perform given tasks.

The top production executive is concerned with actual production only to the extent that he approves the plans developed by staff groups for his department and assumes the responsibility for their accomplishment. If something goes wrong, such as inferior product quality, high-cost operations, lack of delivery according to specified dates, he is accountable for the failure of the production actions whether that failure is the result of planning or execution. As it is, the production executive is the one who worries primarily about the big problems of production and lets his lower-ranking managers, including the supervisory personnel, handle the solution and implementation of the small problems which ordinarily arise in production situations.

It may help to illustrate the scope of execution, if the distribution of responsibilities for production is considered for a moment. An automobile company's top production executive is primarily responsible for the production of x number of cars produced at given cost. Obviously, to achieve low-cost operations (yet in time to meet consumer demand) it is essential to accomplish production without excessive storage, yet without overtime work and pay. The top production executive will worry about completed cars and not about components, for which someone else will assume responsibility. The plant manager in charge of the plant making some of the components is responsible for prompt delivery of parts made in his plant and for the cost and quality of the production units. The various superintendents within a plant are in turn responsible for the production of certain motor parts and components. For instance, the superintendent of the machine shop which makes the engine blocks that ultimately enter the motor assembly must be able to manufacture the right quality and quantity of engine blocks at the right time and cost.

Anybody in a position of authority is responsible for a component depending on his position. While the top production executive is responsible for the whole manufacturing process and another for assembly of the automobiles, the paint shop foreman's responsibility is confined to spraying the cars and keeping the costs within the budget.

The most important man in the production organization is the "forgotten man," the line supervisor. He is really the one who is accountable for production by his responsibility for the ultimate performance of his subordinates. Each departmental activity is assigned to a foreman whose jurisdiction is confined to supervision of a few men—from ten up to a quite substantial number in certain instances. Each foreman is ultimately responsible for performing certain operations on the item or items in question. He usually handles those operations for which equipment located in his department is suitable; and he reports his accomplishments to his superior, either to the general foreman or directly to the superintendent.

The first-line supervisor's accomplishment can be appraised in terms of production units. Note the difference: the supervisor is the only one among the chain of managers whose effectiveness is reflected in tangible evidence. While higher-ranking managers are considered effective if their subordinates are effective, at the foremanship level the usefulness of the product and the cost reflect the supervisor's skill in selecting the right employee to perform the operation, instructing that employee in the performance of his duties, and seeing to it that everything proceeds according to the plans which someone has established for him in a faraway office. The production foreman is then considered successful if the work which falls under his jurisdiction is accomplished in the quantitative and qualitative sense and is produced at low cost and finished in accordance with delivery requirements. In other words, the foreman is successful so long as he adheres to plans which are given to him by engineering planning as to tolerance and structural requirements, processing sequences, and time standards and by the production control department as to starting and finishing dates.

It has been repeatedly stated that production in the modern sense is a matter of fulfilling one's own responsibility. As long as everybody carries his share of the total production load, the component parts of the production plan will be properly carried out.

While the effectiveness of the "higher-ups" largely depends on their leadership ability, good foremanship is not so vitally based upon highly refined skills in dealing with people. Nevertheless, leadership ability and knowledge of good human relations and their proper applications are priceless assets. In a production system in which planning is done by someone else, the foreman's main task is to select the suitable man and give him the assignment in such a way that he understands what he has to do and how he has to do it. Furthermore, the foreman must be able to command the obedience of his subordinates. He cannot succeed without certain inherent human qualities, but the best human qualities are not adequate unless they are coupled with technical know-how in the jobs which fall under his jurisdiction. He must know the jobs and the machines and must have some degree of knowledge of how to run those machines themselves. Unless the foreman has these attributes, it will be difficult for him to inspire workmen to follow him and to command performance and enforce the rules. The foreman's attitude and diligence and his duty consciousness and alertness will be directly reflected in employee performance.

Good common sense and general intelligence must be a characteristic attribute of a first-line foreman. He may have to argue with employees whose logic is often unorthodox. He should be able to cope with these problems and give responsible answers quickly and decisively. Foremen must be men with some sort of a double standard in that they can fit themselves into the management environment as well as into the shop milieu. They must be able to speak the language of the workman and also that of the executive.

As we have seen, the interpretation of leadership qualities is different at the supervisory level than at higher managerial levels. This is natural, since the foreman deals with a different group of men or women than do the managers in higher ranks. Different aptitudes and mentalities require a correspondingly different method of approach. The adaptability of foremen is an extremely important characteristic because the shop foreman is the final link between labor and management. As far as the worker is concerned, the supervisor is the management. It is up to the supervisor to decide who is hired, promoted, disciplined, praised, and dismissed. He is the one who in reality "administers" the labor contract and finds himself always as the first-line arbitrator of conflicts arising out of interpretation of the contract. But above all, the first-line supervisor is the one who "produces the goods" in the strictest sense of the word, not the plant superintendent or manager. The latter produce only in the sense that the shop foremen carry the ball for them.

The work of carrying out production plans falls largely on the shoulders of the first-line supervisor. Thus, he must have the personal characteristics and attributes necessary to be a good leader of men, yet he must have skill and technical knowledge without which the supervisory skill is incomplete. He has to learn how to command performance without arrogance, how to follow orders from those higher up without resentment, how to cope with budgetary problems, and how to get along with a large number of staff personnel who by the very nature of their staff duties tend to butt into the affairs of the foreman. Foremen must take criticism if they are unable to achieve efficiency, and they must be friendly with the worker as long as it does not conflict with the interest of the company, which they must serve without reservation.

SUMMARY

Scope of Production Management

Production management includes all the managerial activities necessary to effective production. Basically, three different groups are concerned with management of production activities: 1) the engineering planning group (design, process, and industrial engineering), 2) the production planning group, and 3) the executive group in the sense of carrying out predetermined plans, composed usually of line management in charge of production.

Process and Methods Planning

First of all, the production plan requires the solution of technical problems. These are determined and solved by technically trained production engineers.

Among other duties, the function of process engineering is to prepare the bill of materials and the process sheet. This is individually prepared for each component or part of the product. The bill of materials is derived from the design drawings, whereby each part found on the design is listed. From this bill of materials it is determined which item will be manufactured in the firm's own plant with its own facilities and which items will be purchased or subcontracted. For each item to be produced by the company as well as for each sub- and final assembly, a process sheet is prepared. The process sheet is a generalized description of the sequence of operations which go to make the finished product.

The above plan is all-inclusive and indicates also the type of machine, jigs, gages and fixtures, tools and other materials which must be used for each operation. The plan then serves the interests of many other planning groups whose main information for further planning purposes is derived from the processing plan. It is used by the industrial engineers as well as by the production control group.

The process sheet can be reviewed by methods engineers to see whether a better sequence or improved production methods which would cut the costs of production can be devised. The tool designer might work closely with the methods engineers and try to design special tools which would help combine or simplify the various operations.

Once the production process is finalized, the industrial engineers take over and determine the time standards on the various jobs. If a wage incentive or piece-rate system is desirable, they determine the appropriate wage payment method. In general, the industrial engineers try to see to it that the human factor of production is effectively fitted into a mechanical environment. The result tends to be minimum labor effort and time and low-cost operations. Thus, industrial engineers ensure the effective utilization of equipment and of the men who monitor the machinery.

Since the production schedule is only a theory and accomplishment depends largely on the willingness of employees to perform according to the standards established by industrial engineers, in job shops wage incentives are designed with the purpose in mind that incentives will inspire workers to produce as the time study determined and as the established schedule intended performance to be. In this respect time study, wage incentive and production scheduling go hand in hand. In continuous production where a conveyor sets the working pace, such a device is not necessary to assure accomplishment of predetermined production goals.

Production Planning

Good plans guarantee, so to speak, the success of subsequent action. Therefore, accurate production plans are of considerable importance. Since busy supervisors cannot be expected to set accurate production plans—particularly plans which would logically fit into the overall production plan—planning in a highly developed organization is done by a production control department.

The production planning procedure guarantees that every production order will progress through the shop in such a manner that it will always arrive in the shipping room in time to fulfill delivery promises. In a preplanned production system, overtime work and pay is an exception rather than a rule. In continuous production, production control is capable of assuring that sales-forecast figures are always met and raw materials always arrive when production requires them, neither too early nor too late.

Execution

Execution is associated with production planning in that it is responsible for activating the plans. Activating is done by making subordinates perform certain assignments and seeing to it that the assignments are accomplished in accordance with predetermined schedules and other requirements. Since activating is based on the relationship between men and men, it is apparent that activating of predetermined production plans requires a good sense of human relations and some knowledge about psychology of the working class (that is, how to deal with men and women of a given mentality). Employees are different mainly because they have certain skills and abilities in different degrees. The supervisory worker selection, based on careful judgment and observation of men on the job, seeks to identify the best man for the job. The supervisor uses essentially a correlational approach and viewpoint whereby attention is focused on within-group (the subordinate group of 10 to 15 men) variance, which is clearly distinguishable from the human engineering approach of the industrial engineer who is mainly interested in the between-group variances as they can be brought to a common denominator through systems of time and motion studies, wage incentives, and other measurement techniques. Proper selection is the first step toward control and performance in accordance with predetermined plans.

QUESTIONS

4-1. What aspects of management are implied by the term "production management"?

4-2. Into which departments is "management of production" divided in large production enterprises?

4-3. Why is planning separated from execution in the modern enterprise?

4-4. In a heterogeneous production there are problems and results. What are the favorable results and how can the problems be solved to achieve effective production?

4-5. Why is modern production of single enterprises called a system?

4-6. If there is a large degree of departmentalization, what is that force which makes everything click in a production organization?

4-7. What is the role of engineering planning in a production system?

4-8. What is the function of technically trained engineers in an organization which is known as a production system?

4-9. What is the function of industrial engineers in industrial enterprises?

4-10. What is the relationship between process engineering and the production planning function?

4-11. What is the function of incentives?

4-12. What is the function of time studies?

4-13. How is motion study related to time study?

4-14. How are process engineering and plant layout engineering related to one another?

4-15. What is the relationship between the process engineer and the industrial engineer?

4-16. How is production design related to process design (process engineering)?

4-17. What is the relationship between the process sheet and the route sheet?

4-18. What are the four production control functions?

4-19. Production planning is often referred to as production control. Why is that so?

4-20. What is the function of the router?

4-21. What is the function of the scheduler?

4-22. What is the function of the expeditor?

4-23. What is the difference between expediting today and that of 20 years ago?

4-24. What is the relationship between the shop foreman and the expeditor?

4-25. What is the function of the dispatcher?

4-26. What is the relationship between the various production planners, that is, the production control people?

4-27. What is the general relationship between production planning and the executive branch (vice-president, plant manager, superintendent, and foreman)?

4-28. What makes execution easy or difficult?

4-29. Who is the most important member of the line management group as far as production is concerned and why?

4-30. What qualities must those people who are a part of the executive group possess in order to achieve effective production?

PROJECTS

4-1. Set up a production system in a company which has the following equipment and employee group:

- Assembly section (electronic devices)
    - Hand tools, jigs, and fixtures (unlimited)
    - Forty skilled employees
- Machine shop
    - Six different milling machines
    - Twenty-five different punch presses
    - Several pieces of welding equipment such as spot-welders and arc-welders

- Several large-tonnage presses and press brakes
- Twenty-five drill presses
- Toolroom equipment
- Seventy-five skilled, semiskilled, and unskilled employees

Paint Shop

- Two paint booths
- Several tanks
- Two degreasers
- Two skilled painters and four helpers

Mechanical Assembly

- Hand tools
- Fifteen semiskilled employees

The company in question receives on the average five military contracts per year for military communications devices (field telephones, switchboards, radar parts, etc.). Design drawings are furnished by the appropriate government engineers.

4-2. Write a letter to any one of our giant corporations and ask for the organization chart of its producing departments. Mention, however, that your interest also includes the engineering and production planning sections. Upon receipt of this information, analyze the company's production system in light of Chapter 4. The analysis should determine whether the company's system is similar to the one described in the chapter. If different, determine how it differs and speculate as to why it differs.

4-3. Describe the engineering planning organization, the production planning organization, the executive branch, and the various methods of departmentalization used by the company which supplied you with the information mentioned in Project 2.

4-4. Determine the size of an enterprise which lends itself to a production system described in Chapter 4 in terms of a) sales volume, b) number of employees, c) number of managers (both in line and staff capacity), and d) dollar value of equipment and plant facilities.

4-5. In this chapter we spoke of departmentalization based on functional skills of planning and executing. The planning function was further divided according to specialized skills and knowledge. Discuss *executive* specialization (territorial, jurisdictional, commodity, operational, etc.).

CASES

4-1. The Breadford Abrasive Company

The Breadford Abrasive Company was incorporated after World War II by Mr. Leon J. Conroy, who had many years of experience in the abrasive business. He had previously been employed in the capacity of production foreman by a nationally known and reputable grinding wheel producer. During his employment, he gained considerable knowledge in all phases of processing and designing large grinding wheels used for grinding work rolls on roll-grinding machinery. Mr. Conroy recognized that following the war there would be an increase in demand for automobiles and that most producers would be using increasingly large amounts of stainless steel for trimming the new models. He also believed that in the manufacturing process of stainless-steel products, considerable hand finishing would be required to remove burrs, slivers, scratches, spots, etc. from the stainless plates by grinding with abrasive wheels on small portable grinders. He accordingly prophesied that a new market for small grinding wheels would develop. After proper investigation several people with savings became interested in his projects.

The money raised was invested in tools, equipment, and raw materials. Plant facilities, no longer needed for production of war materials, were leased from the United States Government at an attractive rental. Mr. Conroy hired acquaintances as production foremen. These were older persons, experienced in the abrasives industry, who had retired and wanted to supplement their income. In view of their qualifications in supervisory jobs, Mr. Conroy gave them a free hand to hire, promote, and fire their own employees. However, he made it clear to them that they were responsible for the errors made by their subordinate employees.

Mr. O'Brien, one of the investors, now the vice-president in charge of sales, was also in charge of warehousing and shipping, since it was believed to be logical that he should be most interested in assuring deliveries to the customers. During the present crisis and bickering, Mr. O'Brien is one of the causing factors. By giving production orders and by harassing foremen, he has created disturbances in production. His schedules were unrealistic and his delivery promises were aimed at getting business rather than making those promises come true. By virtue of his activities, the company had built up a sizable backlog of orders all of which had to be completed before Christmas just four months away. Since the customers pressed for deliveries, Mr. O'Brien spent a great deal of time in the production shop and his secretary dealt with customers, making serious decisions as to delivery dates and specifications. She occasionally made price quotations too. As a result of this, losses were suffered on orders and specifications could not be fully complied with, unless the company spent more money on the job than the sales price warranted.

Apparently, sales were even better than originally expected. By constantly pleasing customer's requests, orders for the small abrasive grinding wheels were easy to obtain and the firm found a highly receptive market for all they could produce. However, this comparative ease was due to the fact that sales were in the hands of an individual who was an excellent salesman, but who knew nothing about the production end of the business. The problems created in the sales department were then blamed on the foremen. It was impossible to meet contracted deliveries, since the man-hours required of each piece of equipment and each man were considerably above production capabilities. To try to meet the specified product designs within the cost and time allowance was to be completely unrealistic. However, management and employees tried to do their best.

When problems in production became rather large and complicated, Mr. Conroy took charge of all the production processes. This was a simple task for him since he had considerable experience in the industry. The only trouble was that while he spent time in the shop, he neglected his duties as the president of the company. Thus policy was not always established and financial decisions were not always made in such a manner that the best interests of the company were served. This situation became aggravated with the steady increase in demand for the company's products. Mr. Conroy preoccupied himself with production problems and neglected the others, which in turn reflected on company profitability. Then the decision to raise prices brought the company price level nearer to the prices of other producers with the result that competition began to be severe.

Mr. O'Brien found that goods were now moving more slowly than previously and felt that the firm was no longer receiving its fair share of the expanding market. He believed that the quality of the product was partly responsible, and after many internal arguments over quality he was permitted to hire an abrasive technologist who would also serve as chief inspector for all products.

The chief inspector began to reject a sizable percentage of the product. One among many orders which the chief inspector gave was directed at changing the sources of supply for raw materials. Furthermore, he changed the sequence of operations in every instance where the change would result in a qualitative improvement, even though the costs were considerably increased. Mr. Conroy differed sharply with the inspector on these changes and ordered foremen to reinstitute the production methods which he himself approved. Much confusion resulted and was followed by a further deterioration of quality.

Since competitors had entered the field, foremen were finding it increasingly difficult to obtain experienced production workers and found it necessary to perform some of the more difficult operations themselves because of the lack of qualified mixers, shavers, and braziers. This was the beginning of company decline. The company started to lose money and continued to do so partly because of quality, partly because of rising production costs. The production cost rose primarily because the company was obliged to work on Saturdays and Sundays too. Since skilled workers were scarce, it was necessary to ask them to work on holidays and work two to three hours more than the regular work shift. Since these men received three times as much as the minimum hourly rate, the company's labor cost was considerably higher than in competing companies. On top of all this, O'Brien, in order to hold onto the regular customers, advised them to return any wheels that they felt were not up to standard. Since warehousing and shipping were also under his control, he made these replacements from stock awaiting shipment to other customers. This interfered severely with orderly shipping, and customers began to complain. This resulted in night-shift operations with workers of lower calibre and little, if any, production experience in the abrasive business. Supervision was poor during the night shift, because first-rate supervisors did not want to work the graveyard shift. Although plant output increased by the addition of the night shift, the rate of output was 30% lower than that achieved during the day shift.

Realizing that the situation was going from bad to worse, the officers agreed on some organizational changes. A new superintendent of production with full authority over production was employed. The chief inspector was directly subordinated to the production superintendent. Shipping and warehousing were taken from Mr. O'Brien and given to a new foreman who reported directly to the president. The superintendent took responsibility for determining delivery promises and shared the scheduling and expediting function with the foremen.

The new organization has been working smoothly since the reorganization. Complaints from customers are fewer and the firm has succeeded in recovering some of the lost markets, although the firm still operates in the red. The president, still interested in production, often walks through the plant and, while observing production operations, makes some on-the-spot changes without consulting the superintendent. The chief inspector still directs the workers when he believes that the percentage of rejects can be improved by his suggestions.

Questions. The student is reminded that the problem has to be handled in two stages: 1) before the reorganization took place and 2) after reorganization. The preparation is similar to the other cases discussed previously.

1. List the symptoms which indicate that this company is not operating efficiently.

2. What causes the problems? List the causes after the symptoms.

3. What do you suggest management should do to eliminate the existing problems a) before the reorganization and b) after the reorganization?

Your task boils down essentially to this:

4. Do you agree with the reorganization?

5. How would you have arranged everything?

6. Was there a production system in existence in this company?

7. Were the responsibilities properly divided?

8. Were there frictions between people?

9. What were those areas in which coordination would have been necessary to efficient production?

10. Was there a need for a production planning department?

11. Was there a need for an engineering planning section?

12. If there was a need for engineering planning, how many engineers with what kind of engineering skill should have been employed?

13. If you were a consultant, what would you have proposed that management do?

4-2. RAMCO CORPORATION

In 1962 the expansion of RAMCO Corporation reached phenomenal proportions. It became one of the largest among the manufacturers of office equipment. RAMCO went through such a rapid development that its production could not keep up with demand. The extraordinary rise in sales volume was associated with the tremendously quick rise in the total demand for the industry's products as well as RAMCO's excellent office equipment. The former, in turn, was caused by the combination of growing paper-work loads and a constantly rising salary level which forced businessmen everywhere to mechanize their clerical operations. RAMCO's excellent office devices resulted from a clever policy followed by its president during the depression.

During the Great Depression, the company was relatively small, but financially it was in an extraordinarily favorable position. The Depression did not hurt RAMCO at all. RAMCO was lucky, rather than clever, that it sold its plant lock, stock, and barrel to a large company a few months before Black Friday and the stock market crash. The company sold at a good price and hoped to build a modern large plant in Chicago. The Depression found RAMCO in a "liquid position." In view of the new economic situation, RAMCO did not build the plant, but instead purchased a plant which had gone bankrupt. Since business conditions were extremely poor, the president of the company decided to produce only to order and devote labor hours to the production of experimental office equipment and spend a great deal of time on research. At the same time, RAMCO purchased every patent (basic ideas only) offered by financially desperate inventors at ridiculously low prices. These patents ranged from portable hand-operated models to fully automatic units for the high-speed production of basic information and records. Since RAMCO had almost unlimited resources, it also acquired the controlling shares of corporations which sold on the New York Stock Exchange way below par value. The president said, "I put all my eggs in one basket—I either win or lose, but I don't hedge."

The basic patents acquired were tested and retested during the depression years. Experimental models were built and RAMCO developed a great multiplicity of lines of office equipment. The applicability of these basic patents was so universal, varied, and diversified that RAMCO could compete with practically anyone in the business. The product design and performance of RAMCO products appeared to be considerably superior to the products of the biggest companies in the world.

RAMCO was fortunate that it sold its relatively large plant when it did, because equipment and the plant in general would have stayed idle during the Depression. With the plant they had, they could produce all the experimental models and take care of repeat orders for former products without too much difficulty. Although it did not operate on a profitable basis, it would be hard to say whether the company was losing money during the Depression. The fact remains that RAMCO invested its time and effort in the future. When the recovery came, RAMCO was in a dominant position. Other companies slept or fought with financial difficulties, but RAMCO prepared itself for the future.

RAMCO's problem now is production, not sale. Even though sales in general declined during the recession of 1960–1961, RAMCO's sales held their status quo. Present production capacity appeared to be adequate during recession times, but in prosperous times RAMCO is unable to meet normal production requirements, even though plant facilities should be able to turn out twice the present output. Since RAMCO products are usually more efficient than competing products, sale is practically no problem. It is believed that a doubling of sales personnel could more than double sales. But since RAMCO has problems in raising production, the management of RAMCO aims at this time at solving the production problem rather than getting a larger share of the market. Regardless of what was done, RAMCO has been unable to cope with the production dilemma.

Until quite recently, RAMCO operated in its relatively obsolete plant purchased during the Depression and used mostly for research purposes. Although the plant operated primarily as a pilot plant during the Depression, its facilities were sufficient to meet the limited demand which existed for office equipment. While other firms increased advertising expenditures to raise sales, RAMCO concentrated on product development and prepared itself for the big day when business would pick up and office equipment could be sold profitably. Most of the work done during these years was engineering research and experimental work rather than volume production for sale. This work produced little if any profit, yet during the Depression it was a better thing to do than fight for the already scarce market and waste effort for that few dollars of business which most companies handled with loss anyway. To substantiate, let us recall that most manufacturers of office equipment were happy during the Depression if they succeeded in covering variable costs and part of the overhead.

When business picked up, RAMCO was in an excellent position to outmaneuver most of its competitors. Sales were at first so profitable that the company raised its sales volume from $5 million to $10 million to $17 million during the succeeding 8 months. The development was so fantastic that the management faced a serious problem as far as production was concerned unless the capacity problem could be successfully coped with. The acquisition of weak companies and bankrupt plants and the new personnel created many problems. Purchase of a large number of plants which used to be suppliers to the company did not seem to satisfy company requirements. It appeared that the company had the production capacity in terms of know-how and facilities, but somehow the total production was always considerably less than the component-part capacity. This did not make sense. Despite plants which extended from coast to coast, production failed to satisfy growing demand. While most companies would consider themselves lucky to be in such a sales position, RAMCO was very worried about its inability to meet market demand. They were unhappy in particular because to maintain these plants production costs rose faster than the sales price warranted, and this despite the fact that company cost structure consisted primarily of manufacturing costs rather than of costs of sale or research. The company is 47 years old, and the present and immediate future, under the guidance of a well-proven management group, can be characterized by new products, increasing sales, ever-expanding manufacturing facilities, and, paradoxically, declining instead of rising profits. This last situation requires a solution today, not tomorrow.

Upon a cursory analysis of the company's difficulties, it appears that RAMCO's method of acquiring small financially weak companies just because they were in the line of business in which RAMCO needed production facilities was not justified. Refinancing weak companies and purchasing their facilities, as well as the organization with it, was a poor policy. The president, however, insisted that in the long run it was better to do so than to build new plants and hire and train their own managerial personnel. While the idea has some merit, it is problematic whether this method can lead to successful management of production activities. The Wheaton division, just to mention one example which produced certain small parts, operates now just as in the past, on a one-man-enterprise basis. The former owner, now the general manager, has designed the jigs, tools, and fixtures, and his foremen are those who develop the production process and schedule and execute production. The same is true in many other subsidiary companies. While each subsidiary had its own "general practitioner" type of engineers performing mechanical and industrial engineering functions, it was apparent even to the blind that these functions were not properly performed. Formal production control did not exist, except in the Baltimore branch, which was formerly one of the largest typewriter companies in the country before the RAMCO Corporation bought up the majority of its voting stock and gained control over operations.

Thus, the general picture boils down to the following: The company is at present a large-scale producer of an extensive line of products and is in both the electronics and the mechanical industries. The majority of operations consist of manufacture and assembly, both mechanical and electrical. Subassemblies are usually made in small subsidiary enterprises, while major assemblies are made in large plants which are scattered throughout the United States for easier distribution. The computer division is located in the Chicago area and is at present the only enterprise which shows profit from its operations. Thus, large sales volumes and future sales possibilities will not bring in the expected dollar earnings. The management of the company at first thought that a rapid acquisition of plant facilities and the more or less indiscriminate use of plants acquired during the Depression of the 1930s accounted for this. However, with the passage of time, it was evident that the products were inefficiently produced. In line with the problem of inefficiency, it appeared that the whole organization needed reorganizing. The problems listed were accentuated by the fact that the company failed to meet delivery promises to distributors and jobbers, frequently leading to the result that customers ended up purchasing a competitor's product even though they were convinced that RAMCO's would serve them better. The major production problem centered around the fact that it was impossible to maintain a continuous flow of production. Since every plant depended on timely delivery from others, retarded delivery of parts caused production delays in a series of enterprises. If there were enough screws and bolts at hand, the plants ran out of some other parts. Somehow there was no system in their production and it has become apparent that unless the company does something about systematization of production, the bright future may turn into a gloomy one.

The president has resigned under the pressure, turning over the management of the business to the executive vice-president—who is 30 years younger than he, but he has remained chairman of the board.

The new president believes that a centralization of management must take place and is against the general tendency to decentralize operations. He contends that too much independence is the trouble in RAMCO and has therefore decided to institute a centralized production control department and a centralized engineering staff which will be located in Chicago. Thus, all design and processing problems will be decided in Chicago. Production control will also operate from Chicago with the help of teletype and instructions will be given through various company-produced electronic communication devices. Punched and coded tapes will forward information of required production quantities to the subsidiaries and reports in turn will come to the centrally located office in Chicago. The president has also outlined his plan to install a $3-million computer to furnish management with information about needed quantities and to calculate market needs better and more quickly than the present hit-and-miss methods of forecasting sales. Greater production flexibility is behind this idea, and operations research seems to be the answer.

The proposition of the new president was taken by most officials with a grain of salt. The former president, particularly, was dissatisfied with the suggestion. Although he felt that the decision was up to the new man and that he himself was probably too conservative, he still believed that such a radical departure from former production methods was not fully warranted. He convinced some of the board members to press for moderation and suggested less radical methods to the president.

Opposition also grew in the various subsidiaries, which felt that a centralized production system would take the initiative from individual plants and would do more harm than good to efficiency. However, moderate centralization was welcomed by most of the larger assembly plants, which for some time had wished for such action.

The general attitude varied. At the time company plans were announced various problems were forecast. Some of the management personnel felt that this was merely an attempt to put new men into jobs and that the company wanted to get rid of the old company leadership in an indirect way. Protests were made, and reference was made to the company's specific commitment that the purchase of a given plant would not mean changes in plant management. It was felt that the new policy contradicted RAMCO assertions that everybody should retain his job provided that gross inefficiency did not prevail. Everybody seems to feel that this new move is a disguise to discredit leadership in the small plants and create big jobs for a few.

Questions. This problem bears similarities to the problem presented in the Breadford Abrasive Company, but the student should note the difference. Breadford is a small outfit, whereas the RAMCO Corporation is one of the world's largest. RAMCO's problems are magnified by the company's operations. Breadford Abrasive produces a few items in one plant; RAMCO produces a whole series of items in dozens of plants. Consider the fact that RAMCO produces, say, 15 to 100 different items each of which consists of thousands of parts: plastic, metal, electronic parts, cables, harnesses of different electronic frequencies, and many other items which may have to be placed into an electronic computer or a device of similar size and complexity. Furthermore, multiplant, multipurpose, and continuous production is combined with intermittent production of parts; at times the product, especially if a part, is reordered several times a year; inventories are depleted and must be replenished; and so on.

1. Analyze the problem or problems of the company by listing first the symptoms indicating that there is something wrong. (Here again the problem must be divided into *before* and *after* reorganization.)
2. List the causative factors in relation to the various symptoms.
3. Suggest solutions.
4. Criticize the actions of the former president.
5. Criticize the plans of the new president.
6. Do you agree with the production policy as it was practiced by the old president?

4-3. ROBERTS ENGINE COMPANY

The Roberts Engine Company, a large firm, has been in business for many years and is engaged in the manufacture of automobile and truck engines. In recent years there has been an increased demand for power lawn mowers, and the company decided to produce lawn mower engines along with their regular line of automobile and truck engines. In the past the company subcontracted the making of pistons and piston rings to the Jones Manufacturing Company, which was a specialist in the field. The Jones Manufacturing Company has a reputation for high-quality work and had shown substantial profits over the past ten years with signs of greater profits in the future, provided that the company was capable of developing an efficient production system.

Because of increased demand for power lawn mowers in the past year, the Roberts Company could no longer produce enough lawn mower engines to meet the demand. The company had doubled its dollar value in the past year and the board of directors of the company decided something should be done to increase the plant's capacity to keep up with the increasing demand for lawn mower engines. As a result of the board's decision, an opportunity arose to purchase the Jones Manufacturing Company. It was decided that, rather than make pistons and related parts, the Roberts Company would move their newly acquired subsidiary to a new location just a few miles away from the parent plant and have it produce the necessary parts.

Many of the key management personnel in the Jones Company were dissatisfied with the decision to relocate their company and many were offered, and accepted, positions with competing companies.

When the Jones Company moved to its new location, new personnel were hired to fill existing vacancies, machines were installed, and plans were set up to start production of pistons and rings for lawn mower engines. These parts would be manufactured by the Jones Company and shipped to the parent plant for final assembly in the engines.

The former general manager of the Jones Company was kept on as plant manager under the new setup, and each company retained its own materials control department, production planning department, product design engineers, and industrial engineering department as if nothing had happened.

Once production got under way, the number of lawn mower engines produced by the combined efforts of both companies was adequate to meet the demands of the market. About a month after the new engines were put on the market, dealers began to receive complaints about the engines. The subjects of the complaints were broken rings, pistons out of round, etc. These complaints were referred back to the Roberts Company. As a result of these complaints, the company's sales of their engines declined.

At a meeting of top management of both companies it was decided that something must be done about the quality of the engines as quickly as possible. New quality control methods were installed all along the assembly stage of the production process to increase the quality of the engines. It was found that the majority of defects resulted from defective pistons and rings. Although the problem was now pinpointed, it still had to be solved. Quality control could separate good parts from bad and stop faulty parts from going on to the final assembly stages, but the cost of producing these rejects was not eliminated. One of the administrative assistants to the vice-president in charge of production was asked to investigate the situation.

The administrative assistant explained that the pistons and rings were faulty because each employee used his own method of working. The foreman was running round like a chicken without a head, giving a few instructions but being mainly interested in seeing that the workers produced something, no matter of what quality or in what way. Furthermore, the young engineer came up with the discovery that it was seldom that the same man operated the same equipment for two consecutive days. The foreman seemed to assign men to jobs indiscriminately. However, the administrative assistant remarked in his report that this could be attributed to the fact that the supervisory personnel had too many people to supervise and that too many duties were assigned to individual production foremen. Thus, for instance, he noticed that the foreman developed the production process on the spot by studying the blueprints for five or ten minutes. These foremen subsequently determined the productive steps and assigned work to the proper machine when the machine became free. When the foreman was pressed, he stood around and practiced slave-driving techniques to get more output per man-hour of labor. At times he even encouraged employees to disregard the specified inspection procedures so that no time would be lost by inspection. During such rush hours production was the byword and quality became of secondary importance. This report presented a special problem for the parent company because it became apparent that the problem was of a different nature than had originally been believed. To solve the problem, the Roberts Engine Company prematurely demoted some management personnel at the Jones subsidiary and filled the vacant posts with management personnel who had formerly excelled at the Roberts Engine Company. The solution of the human problem was now a very ticklish one, especially because it created dissension and tension. The report spotlighted these problems, but it also indicated that the company had become sufficiently large to employ specialized staff personnel to relieve foremen of a great deal of work. Obviously, the Roberts Company had acted unwisely, but the mistake had already been made. It was now important to remedy the error, and this could be done by a production system whereby cooperation between plants could be achieved and production difficulties eliminated.

Because of the high percentage of defective parts, costs rose to a relatively high level, making production of lawn mower engines unprofitable. Parts which were rejected had to be produced again. This could be done solely by extra man-hours of labor after the normal 8-hour work shift. Although overtime work and Saturday work solved the plant capacity problem, it caused a 50 to 100% rise in labor cost. The disturbance caused by defective parts in assembly at the Roberts Engine Company also affected the time and costs of assembly.

The problem was aggravated by a general decline in sales resulting from the qualitative production problem. When the sales of lawn mower engines declined, the Jones subsidiary did not have enough work to keep their equipment busy at or close to capacity. The result was layoffs and employee discontent. While the Jones subsidiary had excess capacity, the Roberts Company still had more work than they could handle with their present work force and equipment. However, communication between the two companies was so poor that the overcapacity in the one company could not be balanced by the undercapacity at the parent company. All these uncovered problems indicated to the administrative assistant that coordination depended not so much on putting one man in an authoritative position, such as making him responsible for supervising two different plant activities, but on establishing a production planning department which would give work assignments from a central office.

After the installation of quality control in the assembly stages, defective engines were eliminated and the sales of Roberts Company began to rise again. But the profits were counterbalanced by the losses created by rejection and subsequent scrapping of many pistons and related parts in the Jones subsidiary. However, when the Roberts Company put a production control department into operation and relieved supervisors of production planning by setting up work loads for both of the related companies, the inspection department reported that out of 100 pistons or parts the rejection rate had declined from 35 to 40% to a negligible ratio.

Thereafter, the Roberts Engine Company asked the administrative assistant to investigate why the sudden improvement. Roberts Engine Company contended that the improvement resulted from putting Roberts Engine Company men into high positions at the Jones subsidiary. However, the administrative assistant pointed out that the improvement had nothing to do with this move, but with the simple measure of relieving supervisory personnel from duties which were not in line with their training and experience.

Questions. The Roberts Engine Company case illustrates the bad effects of factory operations which fail to recognize the need for a production system. As long as the company operated as an independent outfit, the problem could be handled without much trouble. When, however, two enterprises working essentially independently are concerned with the same problem, lack of coordination and cooperation manifests itself in delays, losses, and other visible and invisible occurrences.

1. List the symptoms which show that the company is running into difficulties.

2. List the causes of the symptoms.

3. List possible solutions for each cause which you have discovered. Make a decision as to which of the several possible solutions you would select under the prevailing situation.

4. Look at the problems and explain who it was who failed to make the right decision in the first place.

5. Do you agree with the conclusions of the administrative assistant?

6. By reading the facts as presented in the case, what would you say created the problems? (Be specific, especially if you disagree with the findings of the administrative assistant.)

7. If you were the administative assistant, what factors would you investigate to find the source of the problem at hand?

chapter 5

Production in Small Plants

ROLE OF THE SMALL PLANT

The one-sentence title of an editorial, "America's Big Business Is Small Business," eloquently describes the vital role of the small business in the production economy.[1] The apparent *raison d'être* of the small plant is that, in certain types of production, the small plant can do things better, faster, and possibly cheaper than a large plant can do them. There are apparently situations in which the personal touch is of value. Thus small and large plants tend to complement one another.

With its 4.5 million units, approximately one-half of which are engaged in production, small business evidently represents a significant segment of the American economy. And what is probably more important, each plant has its own unique advantage over its counterpart among the larger and otherwise more efficient business units.

But what can a small plant do that a large plant cannot do? The large plant can certainly do the same thing in a physical sense, but the small plant can get going faster. Rush orders, then, can often be better accommodated in the small plant. Occasionally, the small plant can perform qualitatively better work and meet customer specifications that would be too disrupting in a large plant. Also, the small plant may often accept a smaller profit margin. All in all, the simplicity of operations and the compactness of the small plant certainly help get things done. That the absence of labor unions has something to do with the ability of the small plant to do things better and faster goes without saying.

The advantage of the small plant will be evident in lower price quotations and, more importantly, in shorter lead times. The latter may often be the deciding factor in favor of a small plant. These advantages can, however, easily be lost if rising sales do not go hand in hand with the better production control techniques.

THE MEANING OF "SMALL"

In speaking of small plants, a clarification of the term "small" becomes necessary. The former connotation of small, namely, 50 employees or less, no longer holds true because the relations between size and the number of employees lost its meaning with progressive automation. In an automatic plant, 50 employees may turn out goods in such large volume that the plant cannot be considered small by any measure. The small plant is therefore one which has a low volume of yearly business, has a relatively low investment in plant facilities per worker, and is usually but not always engaged in an intermittent type of production. It should be emphasized that it is possible for a small plant to employ highly efficient production line techniques, but the small plant is still not engaged in the mass production of highly competitive items. Typical small plants engaged in intermittent production are a tool and die shop, an automobile garage, and a repair shop in general. Typical small plants that use mass production methods to produce essentially identical items are a minute car wash, a screw manufacturer using automatic machines, and a bottling plant.

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[1] Editorial, *Advanced Management*, March, 1962.

Small-Plant Management

The small plant is usually managed by practical men on a rule-of-thumb basis. The owner-manager and a few associates make their decisions by relying mainly on their past experiences and without recourse to paper-work systems or red tape of any kind. Managerial skill is usually acquired by copying former superiors rather than by formal academic training. A large part of managerial know-how is therefore based on common sense and practical experience on the job. Instead of paper-work systems, use is made of verbal communication, with all its advantages and disadvantages. Thus, one remembers instead of putting things in writing. Nonetheless, up to a certain output level, this system can be quite effective and the small plant can make up for the lesser degree of mechanization through greater productivity of employees. But exactly in this high degree of informality lie the seeds of bankruptcy so prevalent among small businesses. When the plant ventures into the production of complicated items for which the skill and organization is inadequate, the productivity of employees cannot be maintained at a desirable level and labor costs tend to be higher than originally anticipated. Thus, with the growth of the small plant, the problem of employee efficiency must be solved in order to prevent costs from rising faster than revenues. Since smallness is no excuse for inefficiency and the small plant is subject to the same competitive forces as any other producer, small business must, despite its lesser degree of mechanization, keep up a work tempo capable of achieving a high degree of productivity.

THE PRODUCTIVITY PROBLEM

First in importance among the managerial problems in the small plant, then, is control over labor productivity. As said above, this problem increases with growth. When overseeing becomes obscured by size and when paternalistic control ceases, employee indifference toward managerial endeavors can endanger the plant's profitability. Falling output per man-hour of labor can cause both delays in deliveries and, especially, substantial rises in labor costs that make it difficult to operate under competitive prices. This process tends to go on despite the absence of labor unions and union interference with managerial prerogatives. Unless small-plant management can find ways to control these factors, customer loyalty and the advantages of the small plant over the large one begin to disappear.

The productivity problem, then, may manifest itself in rising labor cost on the one hand and falling output on the other. The latter may have a further effect on labor cost because overtime work, and overtime pay, may be introduced in an attempt to meet delivery dates. Although this course may preserve customer loyalty, it will surely undermine company profitability.

Informality has its advantages, but there is a practical limit which the plant must recognize. When this limit is reached, it becomes necessary to adopt a production control system suitable to the plant operations. The system must not only maintain employee productivity but also control the movement of work and the keeping of delivery commitments without overtime. The system must control or compensate for the shortcomings of most small plants, namely, for 1) insufficient planning ahead, 2) inadequate specialization and systematization, 3) lack of understanding of operational relationships, and 4) unwise adaptation of practices unsuitable for small-plant operations.

The question that arises, of course, is when the informal management must be replaced with a more formal one. As long as the compact work area and the plant atmosphere are conducive to cooperation, production is high enough, deliveries are met, and profits are satisfactory, there is apparently no need to change managerial practices. But when those factors start to become negative, when costs rise, and when plant growth increasingly subjects the plant to greater sensitivity to business fluctuations, it is essential to find ways to have better control over operations. With more frequent layoffs come certain labor difficulties and the feeling of indifference on the part of employees toward the problems of the company. This is the time when it becomes not only desirable but necessary to adapt some sort of production control system that is consistent with the size of the plant but is capable of assuring economical utilization of the factors of production.

Since hiring technical specialists to solve these problems would not pay, the planning work ordinarily done by specialists must be done by the bosses and their foremen. Occasionally, management is shortsighted enough to let employees solve production problems themselves in the hope that it will relieve the busy foreman of some work. That is unwise, to say the least. Of course, the question that arises is how the many managerial functions can be performed effectively by a small-plant organization. Assuming that smallness does not preclude the need for process development, time study, performance control, scheduling and dispatching, expediting, etc., it is questionable how all these things can be done by men who have not been academically trained. Practical experience and the hard-knocks school may sometimes be more instructive than formal education, but learning through experience is far too time consuming. What formal training can accomplish in years may take decades of learning the hard way. Thus, in a highly generalized sense the educational background of small-shop management may not be fully adequate to cope with all the problems that go with running the small plant.

What, then, is the one-capsule formula for managerial effectiveness in small plants? The answer is the need for systems by a company of any size. The only difference is that the system designed for the small plant must be so simple that busy men with only high school or even grade school education can follow it. Common observation indicates that large plants not only know where they are going and how they are going to get there but have control devices to measure the necessary steps toward the desired end. This is exactly what the small business must imitate if it is to be on an even footing with a larger business.

The small plant, within practical limits, needs collection and evaluation of the information necessary for establishing plans and implementing action. It also requires that managerial personnel acquaint themselves with simplified methods of control and the need for written communication to eliminate the inefficiency which lies in too much informality of operations.

The system needed by the small plant to increase production efficiency must keep within the realm of practicality if it is to fulfill its purpose. This implies, of course, that any system must be tailor-made for the particular organization and, under any conditions, be simple enough to be administered by men whose job it is to do everything from preliminary planning to closing out a contract. A successful system is able to accomplish a smooth flow of production and thereby control both costs and the maintenance of delivery commitments. Some managerial time is bound to be spent on planning and implementing the system, but in the long run, supervisory time so spent will not only be recovered but richly rewarded.

Since employee performance and output in general depend on knowing what can be expected of an individual, it is apparent that a time study system is needed as an integral part of the control system. Of course, the question that always presents itself is whether stopwatch time studies or past experiences based on a judgment factor should be used as the basis of performance control. There is no answer to this question unless the individual plant's circumstances, such as dependability of employees, employee skills, supervisory skills, and ability of supervisors to appraise the jobs in terms of time requirements, are known. Nevertheless, it is advocated that the time study should be based on some sort of measurement rather than judgment.

At this point it should also be emphasized that sole reliance on employee cooperation, willingness to give a good day's work for a good day's pay, or on mere good human relations is out of place in most industrial settings. Only modern psychology can adequately explain why, but most employees need control to perform as required.

TIME STUDY IN THE SMALL PLANT

Barring availability of time study experts, the foremen must learn something about work measurement so that they can measure performance with a stopwatch and can set standards that will serve all sorts of planning and control purposes. The system is described in the following paragraphs.

Time study ordinarily begins with motion study. In the small shop, however, the order quantities are so small and the repetitive nature of the job is so unlikely that it would be unwise to make a careful motion study. For that reason, a mere cursory study of the motions involved must be made. Subsequently, employees must be instructed to follow that method: where the raw material should be kept, where the tools should be laid down, and when the right and left hands should be used. The work assignment and the accompanying instruction should simultaneously constitute the determination of the motion pattern. Evidently, this cannot possibly determine "the one best way," but it will probably be a better method than the worker would use by himself. Too much accuracy in the motion study end of the supervisory work would be almost wasteful, at least as far as small business is concerned.

Time study should follow motion study. The time study itself, just as the motion study, must of necessity be simple enough that the foreman does not even need pencil or paper. The stopwatch should merely be started when the worker reaches for the workpiece and stopped when the work cycle is completed and the workpiece is deposited.

A decimal stopwatch will facilitate calculations, but it may be a complicating factor and a normal stopwatch may be suitable for small-plant purposes. If the regular timepiece is used, it should be started by moving the side slide toward the crown. When an interruption occurs, the foreman should move the side slide down. This will stop the watch. To continue from the point where the watch was stopped, a mere flick of the finger will, by advancing the side slide toward the crown again, restart the watch. If the employee does something that is not a part of the job, it is essential to stop the watch until he begins to work on the job itself. Accordingly, it should be emphasized that while time study takes place, care must always be taken to avoid measuring other motions than those really a part of the job. Employees tend to add a few extra motions in order to gain a bit more time on the job than is actually necessary.

Between measuring two work cycles, a quick look must be taken at the watch when the workpiece is being put down and, simultaneously, the crown must be depressed to return the hand of the watch to zero. This is called the snap-back method of timing. Timing of work cycles should continue until it is noticed that the performance times tend to repeat themselves within a small range of variation. The foreman should merely look for the most frequently appearing figure that can, in such simple time study, be accepted as the time necessary to do the job. In normal time study practice this is called the average time, and subsequently it may become the so-called base time; that is, it may be accepted as the normal time required for the performance at hand and upon which allowance calculations will then be based. No pencil is needed to remember the most frequently appearing figure.

It is assumed, of course, that the foreman knows the job and that the employee cannot easily mislead him into thinking the job would take longer to perform than it really should or be more difficult than it actually is. In the case of a slower-than-normal worker, the foreman should adjust the time by mentally prorating the slow performance into a normal one. If the worker performs at a faster than normal rate, the foreman should add a certain percentage to the time. In normal time study practice this is called rating. Obviously, the foreman cannot be an expert on rating, and he should therefore not attempt to measure slowdowns unless they amount to 50% or so. A 10 to 20% slowdown is difficult to measure by someone who is unfamiliar with time study practice. Nevertheless, the first-line supervisor is usually able to decide whether the employee to whom he assigned the job works at normal pace. If he does, the time that the stopwatch recurrently indicates can be accepted as the time needed to perform the job.

Finally, the foreman will have a pretty good idea of how long it should take to perform the job, and on that basis he can calculate the output that can reasonably be expected of the worker per hour and per day. This will be the basis of work loading and scheduling on the one hand and performance control on the other.

The fact that a company has time study data available, no matter how reliable and accurate they may be, will not automatically assure better production and better control over employee performances. Although the mere knowledge that time studies are being used will create a psychological framework within which employees are more apt to work and be more careful about loafing or horseplay, the time study must be used to have meaning. As a rule, the workers will attempt to perform, and the chances are that they actually will perform, somewhat better than they otherwise would. The newer employees tend to perform as required. Strangely enough, and this is a complicating factor, inadequate performances will most likely be found among older rather than newer workers. Old-timers are more or less accustomed to work at an easygoing rate, and time study may well disclose that their production, in relationship to the expected performance, will fall way below what is considered normal.

OUTPUT DETERMINATION AND CONTROL

Once the base time is found, an arbitrary figure, say 30%, may be estimated by management to compensate for delays such as talking on official business with the foreman or roving inspector and human needs such as getting a drink of water, washing up for lunch, and taking a coffee break. In a scientifically developed time study, this percentage is usually estimated with a great degree of care. In the small shop, it is up to management to determine a reasonable amount of time employees are legitimately entitled to waste or use for other than productive purposes.

Thus, the base time plus the allowance equals the time standard. It may seem that 30% is quite liberal, but a careful look at the small shop will no doubt reveal that 30% waste is by no means considered excessive. Very few small shops operate at the theoretical 100%; rather, they operate at a considerably lower efficiency rate. The calculation based on 30% allowance and an actual performance of ½ minute is as follows:

Base time	+ allowance	= standard performance time	output quota or output requirement
0.50	0.15	= 0.65 minute	90 pieces per hour

When one is not accustomed to speak in hundredths of minutes, it is simple to convert back to seconds by multiplying the base time, or the standard time, by 60 and putting the decimal point where it belongs. Thus, $0.50 \times 60 = 30$ seconds, or the standard time is $0.65 \times 60 = 39$ seconds.

The determination of the hourly output quota is quite simple. The 60 minutes of the hour must be divided by the standard time per piece, and we have

$$\frac{60}{0.65} = 90 \text{ pieces per hour}$$

if the figure is rounded off.

Application of Standards

Once output quotas are established before, or, at least, immediately after, the job is started, control over employee performance is rather simple. With the output requirement of the preceding example, an order for 900 pieces would take one 8-hour day plus 2 hours on the following day. If an employee starts on the job in the morning, the foreman knows that he should be almost finished at the end of the day. A superior employee might turn out all 900 pieces by the end of the day, 2 hours ahead of time. What is of considerable importance, however, is that on the basis of the expected work output it is possible to keep track of the performance of most workers. Supervisors will know when new assignments are due and can plan daily work-load assignments accordingly. Such a system will, of course, also keep the foremen busy, if for no other reason than that they have to remember who is doing what and when that job is supposed to be finished. The business of remembering things may be facilitated by a shop blackboard on which foremen may make notations. The blackboard can thus be very useful in keeping track of work in process and the men who were assigned to do it.

As has already been said, a mere knowledge of output requirements is no guarantee of proper performance. Output quotas merely facilitate supervisory control over shop employees, but it is still the supervisor who must command action and enforce obedience. If there is a quota system but it is not enforced, production will still be deficient. For that reason, a constant check on workers is necessary, assuming there are no self-control devices such as the piece rate or the wage incentive system. If supervisors feel that they are too busy to keep track of employee performances and police the shop, the performance report may be a very useful device.

A performance report is especially practical if time clocks are in use. The employees check in and out on job assignments, thereby recording the time spent on each job, and afterward they indicate the number of pieces turned out during the time interval. It is then easy to compare actual and expected, that is, quota, performance. If the employee turned out the required number of workpieces, his name is shown on the left-hand side of the daily performance report; if not, his name is shown on the right-hand side. These reports can be compiled from the job cards or, in their absence, from the employee time cards by someone in the office or by a timekeeper. The reports should be placed on the desk of every supervisor no later than an hour or so after the beginning of the workday. If a particular employee is frequently listed on the right-hand side, it is reasonable to assume that he is either unable or unwilling to turn out a fair day's work. At that time some action, whether disciplinary or remedial, can be taken. As an alternative, the performance list might be posted on the bulletin board. It might have a psychological effect on the worker in question, because no one likes to look incompetent to his fellow workers. This may not always be effective, however, and then the supervisory scolding may be necessary.

Deficient performance does not necessarily mean that an employee is incapable or lacks diligence, however. Employee skills and aptitudes may vary with the job assignment. An employee may be found on both sides of the performance report, which merely indicates that he is better on some jobs than on others. Thus, with the help of the daily performance report, a better job assignment can be made, and this is probably the most important value of the report. The trouble often is that supervisory personnel are at a loss when they must appraise worker talents.

The performance report may also reveal an employee's preference for or dislike of a job, since work that is disliked is performed with less enthusiasm and consequent lower output. Also, care must be exercised in recording the output. If embarrassment or supervisory scolding may result from a deficient performance, employees have no compunction about altering their output reports.

By the use of the methods described, an almost perfect control over employees' time, effort, and output can be attained without making obvious watchdogs out of supervisors. Breathing down the necks of employees becomes largely unnecessary, since it will become evident which worker is performing in accordance with requirements and which one is not. As soon as employees are aware that daily performances are carefully recorded and evaluated, they tend to become accustomed to putting in a good day's work. In small plants of the four- to five-employee variety or in job shops where production calls for only a few pieces at a time, this type of control may be superfluous because one does not lose track of orders that easily. In such plants it may be better to make assignments of jobs in multiples. The employee is, in such situations, given two jobs at once. One is a fill-in job which is not time-bound; the other is the scheduled job. As soon as the employee has finished his scheduled job assignment, he is supposed to go on to the fill-in job without bothering the foreman. When the foreman sees the employee at work on the fill-in job, he can decide on the next assignment and fill-in job for that employee. In an organizational setup of this kind, forward planning cannot possibly represent more than a few hours. Unfortunately, however, even this amount of planning is seldom practiced in small shops, and assignments are made on the spur of the moment. That employees take advantage of planlessness is not surprising. Most waste of time occurs between jobs when the employee fails to report that he has completed the work he was assigned.

MANAGING PLANT OPERATIONS

Because we have been talking of supervisory control over employee performances, the reader should not assume that that is all the supervisor must do in a small plant. A large part of supervisory time is taken up with planning the allocation of work load; selecting employees for particular jobs; directing and controlling, by human relations techniques, employee behavior on the job; and keeping track of production in relation to commitments.

Since staff experts are usually not available, every decision is made by the owner-manager and his foremen. Here we are dealing with a typical line organization in which the decision is made at the top and implemented and detailed at lower levels. The small plant has a very simple organization which tends to correspond to the size of the plant itself. The owner-manager may have a superintendent who shares responsibility for production; the latter may be aided by two or three foremen who supervise ten to fifteen employees each. Unless he is helped by a system that is able to give automatic or remote control over employee performance, the supervisor may spend a great deal of his time on disciplining or watchdogging. If he is relegated to performing all those duties, he will evidently have to neglect some other important aspects of production management. Establishment of procedures capable of facilitating the managerial process is, then, one of the prerequisites to orderly production.

PROCESSING AND ROUTING

From the management point of view, production starts with determining the path the product-to-be will take from the raw material stockroom until it reaches the shipping department as a finished item. We have been discussing the performance problem not so much because the processing problem is less important as because the former is a greater problem in small plants than the latter. The processing decisions are also made informally, but they require more technical competence. Processing decisions can be made any time the boss and his supervisors get together and exchange ideas about the possible use to be made of available equipment in performing given work. Arriving at the best method of processing is a matter of finding the shortest as well as the most practical way to attain necessary production. By "shortest way" is meant the method with the least number of production steps.

In the solution of processing problems there are many alternatives, and some of them are more practical under certain circumstances than others. Since by "process" we mean breaking the job to be done down into smaller segments, it is essential to make a specialized activity of each step. Care must be taken, however, to eliminate unnecessary handling and transporting from one machine to the next. Thus, if combining two operations would raise operating efficiency, it is advisable to perform the two operations at one work station, and possibly with one setup. When several methods employing different equipment are equally applicable, it is necessary to pick the method which is the cheapest yet takes the shortest period of time to complete, provided, of course, that the required production equipment is available. Since the small shop has equipment in limited number and variety, the choice between processes is, in part, determined by the equipment. Although there are virtually thousands of ways to perform a given production operation, which method is used will always depend on the tools and facilities the company has. Cutting by torch, for example, may be the most economical method, but if flame-cutting equipment is not available, a saw or some other machine will have to do the job. Small-plant equipment is sometimes so inefficient that it might even pay to subcontract an operation to another small plant which has a more desirable machine for a specific operation.

The question that may arise is who is to take care of design problems. The product design, barring the possibility that the owner is the designer of the product he manufactures, is usually done outside, because most small plants find it cheaper to hire an engineering consultant than to maintain an engineering staff which would often have little to do. Furthermore, design considerations usually go beyond the scope of the knowledge of the average small-plant management, although one should never underestimate the skill which some small-shop people have. Hiring a design consultant does not, of course, preclude minor design alterations in connection with process design. The original design may not be suitable to economical production, and the foremen and supervisors might have excellent ideas for minor design changes that will facilitate production of the product.

ESTIMATING

Some of the processing work is already done at the time the plant decides to solicit an order. The customer inquiry initiates some get-together among management during which processing considerations are discussed. More will be said about this later; it is enough at this time to know that costs and processes are determined at the time the order is solicited. It usually takes several days for the processing considerations and cost implications to be extracted from informal discussions, for projecting possible production problems connected with the order, and for ironing out the anticipated problems by the combined effort of the boss and his foremen. Of course, in a small garage, the procedure is even less complicated, because the worker might merely see what must be done and tell his foreman, who then authorizes the work to be done after the approval of the customer.

In line with the customary informality, the whole estimating procedure may be written on a scrap of paper or just remembered by the men involved. Since the actual signing of the agreement between the small plant and the customer only finalizes the process which was considered prior to accepting the order for manufacture, most problems are already worked out, at least theoretically. The start of production will merely necessitate a bit more careful consideration of the same problems and detailing some of the processing considerations, such as determining the tools, the exact tolerance requirements, and many other details which are handled in large companies by engineers and draftsmen. By this time some of the snags which were not anticipated in preliminary plans have also been uncovered and the supervisory personnel actively work on their elimination. This is the time when the ball begins to roll, and many activities related to production will take place simultaneously.

The men in leadership capacity in a small plant are extremely busy. They have to do everything, even to chasing after the forklift operator and going to the stockroom for the necessary raw materials. Unless there is a system that makes employees control themselves, such as a wage incentive system, or that relieves the foreman of constant surveillance, such as the performance control indicated previously, the foremen will not have time to effectively manage the multiplicity of operations under their jurisdiction.

PRODUCTION PLANNING

The term "production planning" covers a lot of ground. Since the men in authority are not aided by staff experts, every phase of planning, both quantitative and qualitative, comes under the jurisdiction of first-line supervisors. This might create the impression that these activities are totally different and would be carried out better if assigned to separate individuals. Nothing can be further from the truth; here we are merely discussing functions which must be performed either by the supervisor or by someone on a part-time basis. Probably the best way to look at it is that the supervisor in a small plant, as opposed to one in a large plant, wears several hats. What we shall do here is explain what duties the supervisor performs when he wears a particular hat.

Scheduling. Orderly scheduling depends on gathering information about the various ingredients. Once the time needed to perform certain activities under the jurisdiction of a supervisor has been ascertained, the setting of starting and finishing dates is relatively simple, provided that work standards are enforced. Barring the occurrence of unforeseen problems such as breakdowns, shortages in materials, and strikes, enforcement of standards tends to result in orderly shipments.

Planning and scheduling is, of course, not something which any supervisor can do in a vacuum. He must have a pretty good idea about the production process, the sequence of individual operations, and the availability of equipment needed to perform the operations. This involves, among other things, the consideration that time as well as physical availability of the machines must be carefully meshed to perform operations in the required sequence. The work load assigned to a particular machine cannot exceed its capacity as expressed in hours. Taking the above considerations for granted, it is easy to calculate departmental work loads by merely adding up the various operation times on each order, multiplying them by the number of units needed, and comparing the total backlog of work with available capacity.

Assume that five additional orders are received, each of them calling for 100 workpieces. Assuming the use of an 80-ton press and 0.50 minute for each operation on each order, it is easily calculable that the work load is

$$5 \times 100 \times 0.50 = 250 \text{ minutes}$$

Now, if we add 10 minutes per order for setup time, the work load is exactly 300 minutes which must be loaded, or backlogged, to the 80-ton press. That is, this amount of time must be allocated to the machine in light of the various wanted dates on the orders. The chances are that the orders must be delivered at different dates. Occasionally there is a conflict and two orders require the services of the same machine simultaneously. In that case the foreman must decide which order should be run first and which can be postponed.

It must be evident by now that the worker can easily upset predetermined production plans merely by taking his time in performing a given operation. If a given machine is tied down longer than the foreman had anticipated, delays and bottlenecks can easily develop. For that reason emphasis has been placed on performance control.

Once the work load for a week is expressed as, say, 500 man-hours of labor, the question that arises is how it can be met if only 380 man-hours are available from a 12-man department. Any supervisor will know that it will not be easy, and it must be determined with care who should be assigned to which job to meet shipments without overtime work and pay. Because the right man on the right job can turn out more per hour than the wrong man, work-load allocation requires not only work-load appraisal in terms of orders, sequences, and capabilities of machines but also appraisal of men. Furthermore, it is essential to assign men to machines equitably in the sense that every day of the week is well balanced with work, and not that the first few days are slack and the rest overloaded because lost time must be made up. Problems, conflicts, and other production bottlenecks must be anticipated, and one must work on those jobs first which can be shifted to an earlier period and allocate the employees, and machine time accordingly.

To appraise the work load on each machine, a simple system can be advantageously used. It consists of a block of wood (equivalent to control charts) with two rows of nails, as shown in Fig. 5-1. (For a more modern version of a pegboard, see Fig. 5-2.) Each set of two nails represents a given machine; the top nail is used as a pin for waiting orders, or operations, and the bottom nail as a pin for orders in process. If on the top nail a whole stack of work slips, or job cards, is waiting, the foreman presumes that the work load is heavy. This might be misleading unless he also takes a look at the size of the orders. A whole bunch of work orders may represent only a series of half-hour jobs, whereas one slip may in itself represent an 8-hour job.

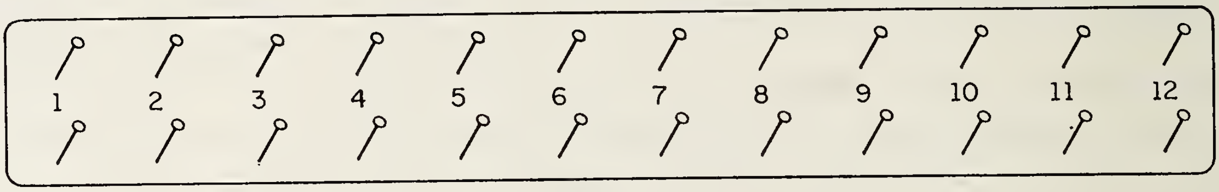


Fig. 5-1

With this system of machine loading, the foreman can always see how many jobs await processing on any given machine and can plan the allocation of work loads much easier than by keeping all the information in his head. Since wanted dates are written on each job card, job priorities can be established by juggling the job cards to place the most important order in terms of rush or date always on the top of the nail, the next to be worked on. In some shops, management may follow the policy of "first come, first served" and schedule work accordingly. This would then mean that the next job taken off the nail is the one on the inside. This might be the system in many repair garages. When the job is started, the slip is taken off the top nail and transferred to the bottom nail, where it stays until the job is completed. Finally, the slip is taken off the nail; the time spent on the job and other pertinent infor-

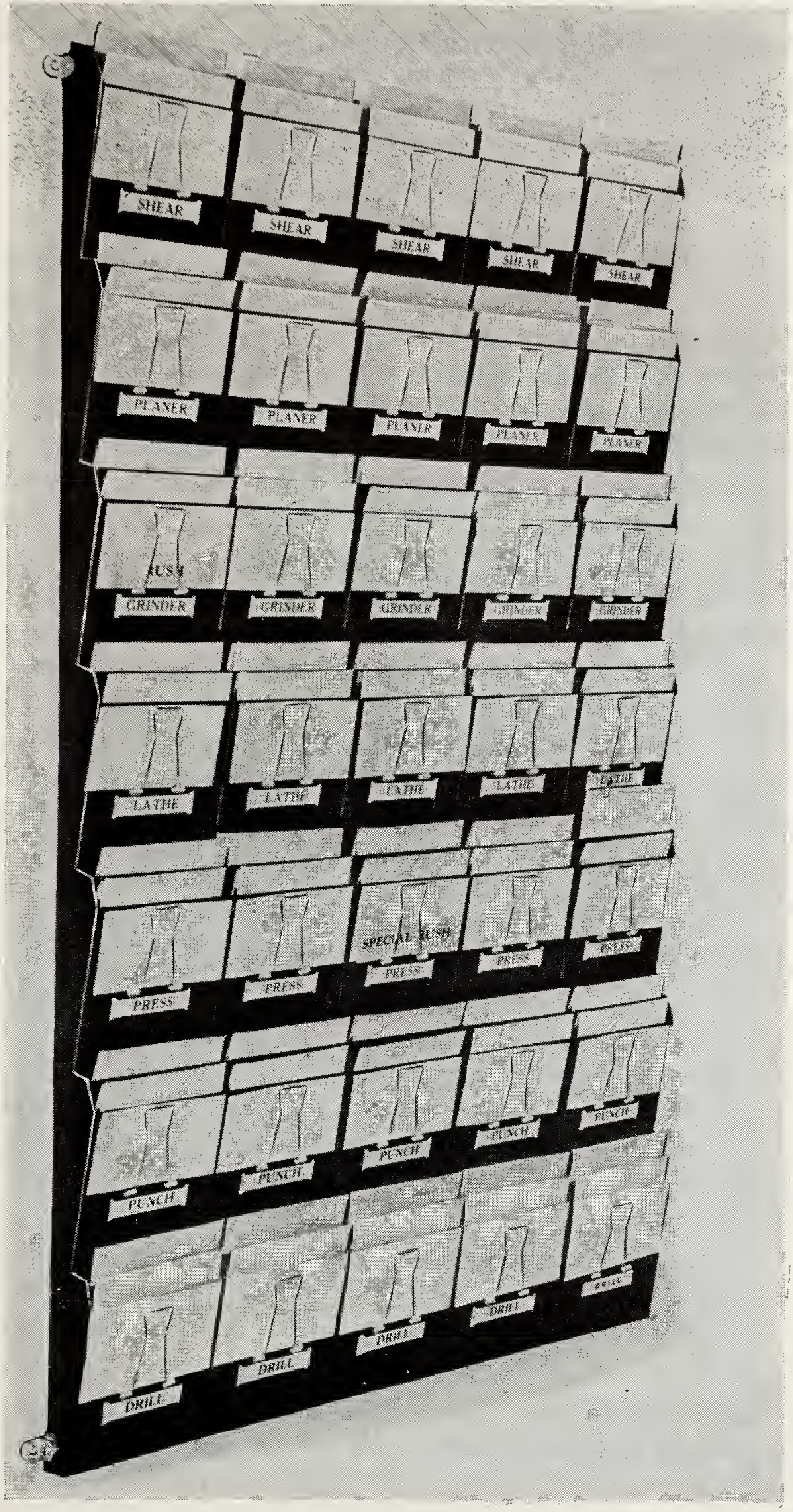


FIG. 5-2. Scheduling and job assignment board. (Courtesy of Victor Business Machines Co.)

mation is recorded; and the slip is sent up to the office, where it can be used for a check against planned performance, for cost accounting, for future cost estimating and bidding, or for any other purpose. If the employees are on incentive pay or piece rate, the same slip can serve as a basis for rate or bonus calculation. Furthermore, the job slip can aid in the preparation of the daily production report, as discussed earlier.

While this kind of scheduling is only pseudoscientific, it is at least a system and is better than none at all. It makes it possible to see what is being worked on and what jobs are awaiting processing, and it is quite helpful in appraising work loads; but it is by no means an accurate production planning system.

As the work load and the number of machines in the plant grow, this system may also become obsolete, and it is important to notice when a system fails to accomplish its intended purpose. Also, the supervisory personnel tend to become overburdened, and one must then think in terms of a more sophisticated system. Actually there is a dividing line—but a very difficult to find dividing line—at which a small business becomes a medium-sized business and must be run differently. When bottleneck stations, delays, and other problems—primarily cost problems—become frequent, the chances are that the plant has outgrown the system at hand and needs one better suited to a more voluminous business.

Although there is an informally established route, the need for a more formalized system is imminent. The job card has so far served only two purposes: machine loading, or scheduling, and as a job card. The job card was pinned on the loading board by the supervisor, as shown in Fig. 5-3. By pinning it there, the supervisor could visualize the work waiting for a machine. Now the same idea can be extended a bit and the job cards can be arranged on a paper strip in the order in which the operations must be performed, with the first operation on the bottom of the strip of paper and the last on the top. The length of the tape will depend on the number of operations. The beauty

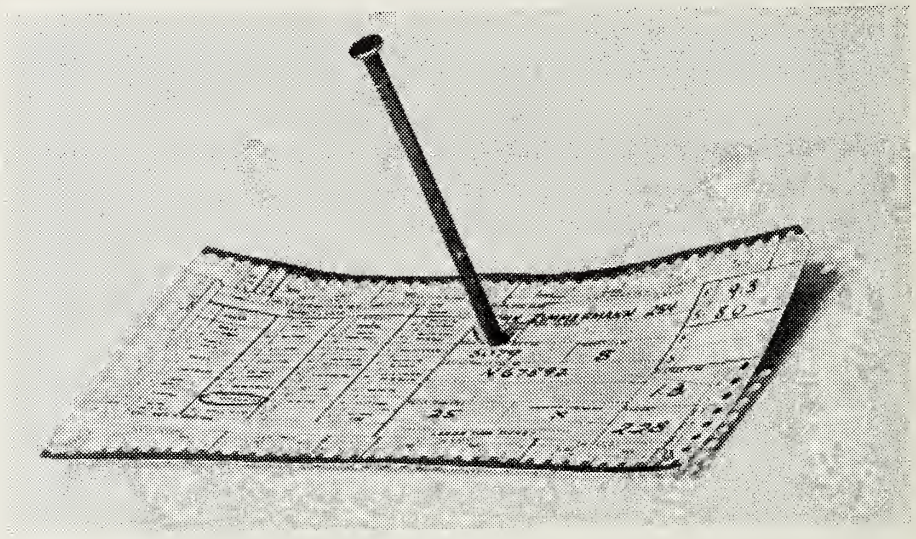


Fig. 5-3

of this system is that it is hardly different from the former method of using job cards, but the fact that the cards are so organized that the relationships between the various operations are apparent makes it easier to load the machines and allocate the work in the appropriate order of importance. This can be significant because operation 3, for instance, cannot be carried out until operation 2 was performed unless operation sequences are interchangeable between 2 and 3. Sheets can be made out with carbon or written out with ink in duplicate. The duplicate copy may be used as item identification and tag along as the product moves from machine to machine. The forms and the system are shown in Fig. 5-4.

The top part of Fig. 5-4 is the control card, which summarizes the results by adding up all the labor time which was spent on the various parts and operations. This can be compared with the budgeted labor time, which was an informal estimate of the time requirement to complete the job. The rest of the information on the control sheet is self-evident.

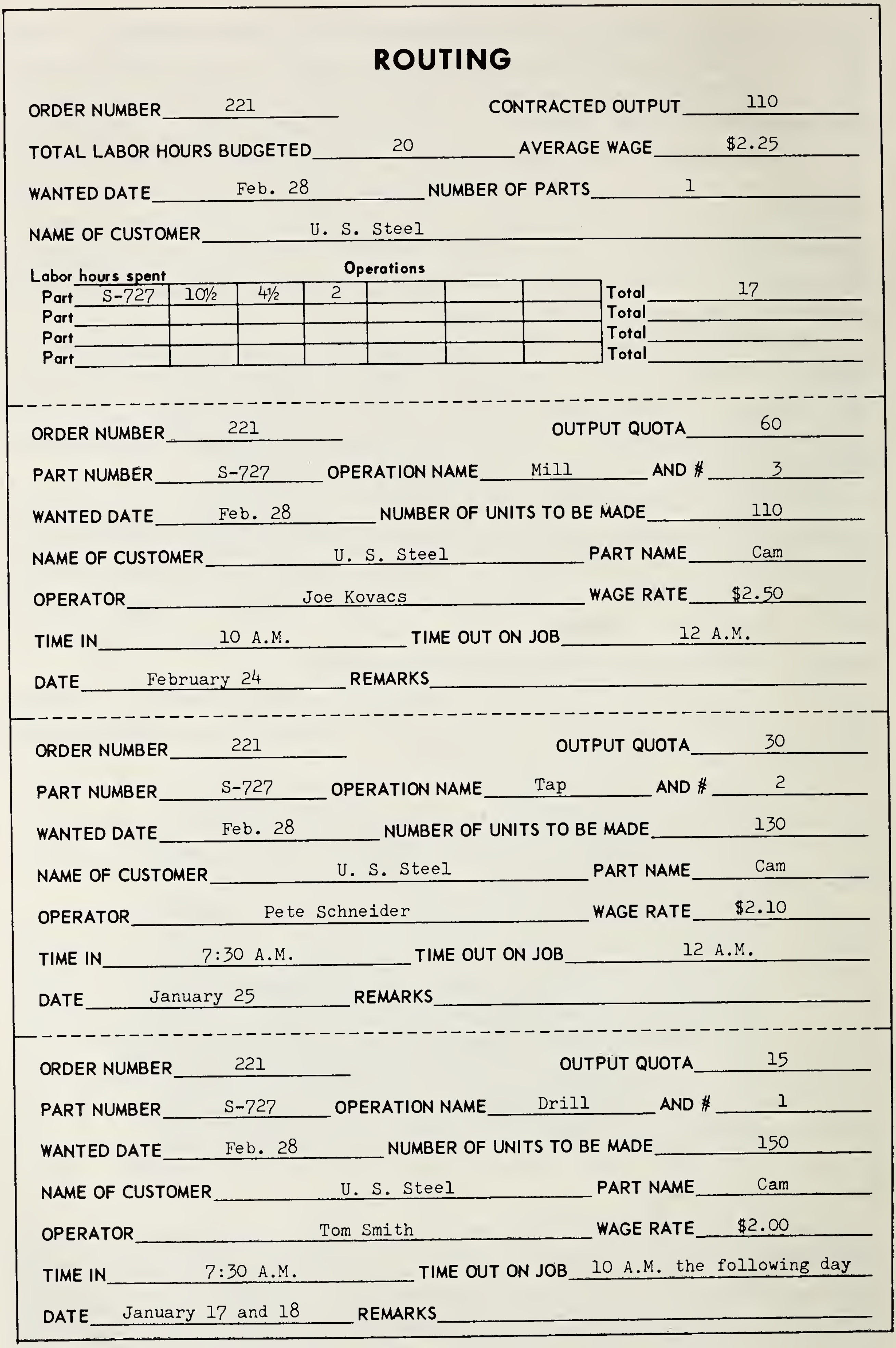
The reason why operation 1 is at the bottom of the paper strip is that the operator after finishing the job will tear that portion off at the perforated line and deposit it as a job slip. On it he writes his name, his wage rate, and the number of hours he spent on the job. The same information might be filled in by a timekeeper if the plant is large enough to employ one. Otherwise, it can be filled in by either the worker or his foreman.

The rest of the sheet may be attached to the skid, container, or product. The strip thereby also serves as a move card, because it is readily apparent where the product will have to move next.

These sheets should be filled out in duplicate, because the first copy is torn up into sections—in this case into four sections—and the various operations will be pinned on the loading board as indicated previously. The control sheet copy goes to the office.

The reader might have noticed in Fig. 5-4 that each operation requires a different number of output units, whereas the contract calls for 110 pieces. Furthermore, operation 3 must end up with 110 pieces, the exact amount of the contract. Apparently this is the last operation. The first operation should result in 150 pieces, that is, 40 pieces more than required. This might be a bit exaggerated, but the surplus should compensate for the normal rejects. Thus, the small-shop foreman will estimate how many extra pieces must be produced to end up with the contract quantity of 110 pieces. Actually, the expected rejects between operations 1 and 2 are 20 pieces; between 2 and 3 they are also 20 pieces.

The various parts of the form will be distributed as indicated in Fig. 5-5. The production quota, written possibly with red pencil on the top of the job cards, is important to both the supervisor and the worker. The supervisor knows what to expect (actually, he is the one who determines the quota on the basis of a quick time study or his own past experiences) and as far as the



ROUTING

ORDER NUMBER 221 CONTRACTED OUTPUT 110

TOTAL LABOR HOURS BUDGETED 20 AVERAGE WAGE $2.25

WANTED DATE Feb. 28 NUMBER OF PARTS 1

NAME OF CUSTOMER U. S. Steel

Labor hours spent	Operations						
Part S-727	10½	4½	2				Total 17
Part							Total
Part							Total
Part							Total

ORDER NUMBER 221 OUTPUT QUOTA 60

PART NUMBER S-727 OPERATION NAME Mill AND # 3

WANTED DATE Feb. 28 NUMBER OF UNITS TO BE MADE 110

NAME OF CUSTOMER U. S. Steel PART NAME Cam

OPERATOR Joe Kovacs WAGE RATE $2.50

TIME IN 10 A.M. TIME OUT ON JOB 12 A.M.

DATE February 24 REMARKS

ORDER NUMBER 221 OUTPUT QUOTA 30

PART NUMBER S-727 OPERATION NAME Tap AND # 2

WANTED DATE Feb. 28 NUMBER OF UNITS TO BE MADE 130

NAME OF CUSTOMER U. S. Steel PART NAME Cam

OPERATOR Pete Schneider WAGE RATE $2.10

TIME IN 7:30 A.M. TIME OUT ON JOB 12 A.M.

DATE January 25 REMARKS

ORDER NUMBER 221 OUTPUT QUOTA 15

PART NUMBER S-727 OPERATION NAME Drill AND # 1

WANTED DATE Feb. 28 NUMBER OF UNITS TO BE MADE 150

NAME OF CUSTOMER U. S. Steel PART NAME Cam

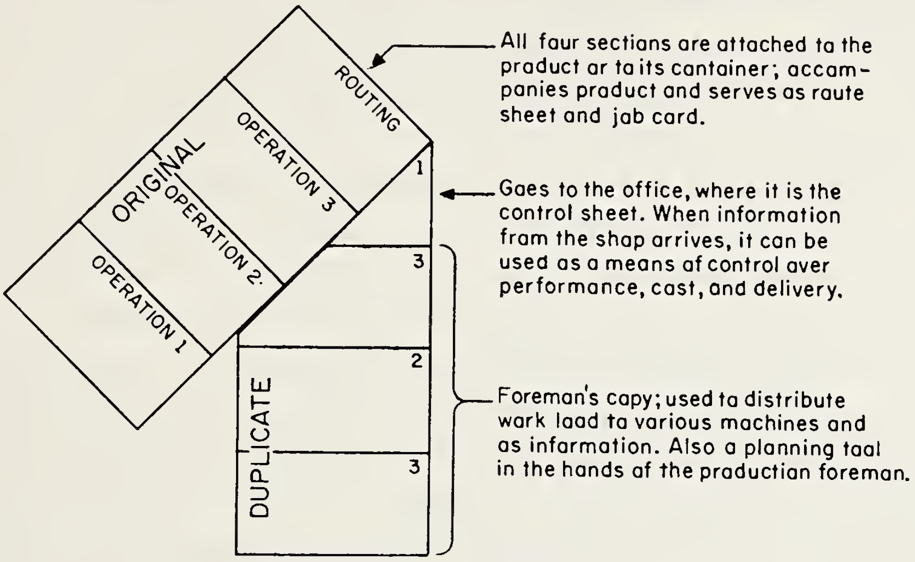
OPERATOR Tom Smith WAGE RATE $2.00

TIME IN 7:30 A.M. TIME OUT ON JOB 10 A.M. the following day

DATE January 17 and 18 REMARKS

FIG. 5-4. The route sheet for a three-part process.

worker is concerned, this is what management expects of him. The quota must be put on the individual job cards as soon as practicable. The fact is that employees will produce this quantity, provided, of course, that it is reasonable in the sense described earlier: a fair day's work for a fair day's pay. It must be based on a normal worker's performance under normal working conditions and under normal work pace; that is, it must not be either the slowest or the fastest performance.



All four sections are attached to the product or to its container; accompanies product and serves as route sheet and job card.

Goes to the office, where it is the control sheet. When information from the shop arrives, it can be used as a means of control over performance, cost, and delivery.

Foreman's copy; used to distribute work load to various machines and as information. Also a planning tool in the hands of the production foreman.

Fig. 5-5

Both the part name and number must be written on each portion of the sheet to avoid possible confusion. While several items might be called by the same name, only one will carry a particular part number. If two parts carry the same name and number, it may be an error, but it is most likely that two different orders contain a common part. Standardization of parts may make products cheaper. Thus it is possible to have parts in any one product that are common to many other products. For economy of setup (one setup for two or more orders) it is advisable to lump the two orders together, but care must be taken not to mix the two because the problems created would cause more damage than the extent of the savings in manufacturing costs. In small companies, however, it is not too often that two or more orders can be combined. When it is possible, confusion seldom results, because both the products and the various operations involved in making them are relatively simple.

To consolidate the knowledge gained so far, let us review the procedure advocated for a small-production enterprise in need of a simple but effective system.

1. Determine the production process and then use the processing as the basis for filling out the forms, but particularly to arrange the operation sequences.

2. Determine the time allowed for each operation, prior to or right after

the operation has started, by taking a time study. A quick study is often enough to determine a representative time required per job cycle.

3. As a corollary of point 2, establish the output quota. The worker is interested not so much in the time per unit of output as in the required number of pieces per unit of time.

4. Actually, this step is taken when step 1 is taken. This is the moment when the route sheet is prepared in two copies and the foreman removes his copy of the route sheet. The control sheet, the top section, goes to the office, where incoming information from the shop will be recorded on it. The foreman pins the various operations that fall under his jurisdiction on the appropriate nails, which is another way of scheduling and allocating work to different machines. Additional information relevant to the performance may be scribbled on a blackboard so that the foreman always knows what happens. This will facilitate scheduling and assure the equitability of workload distribution. The pegboard is used merely to check the schedules so that delivery commitments are met without undue reliance on supervisory memory.

Despite the chronological presentation, it should be understood that these activities are not clearly separable but that many of them take place simultaneously. Imagine a busy machine shop where most of the planning is left to the foreman. It can be assumed that deciding and planning will be done pretty much at the same time. No practical man acts on the basis of intuition; he relies mainly on experience and well-founded plans that worked in the past. In other words, that the decision is quick does not imply that it lacks careful planning. Imagine the cartoonist who makes a quick but perfect sketch of a sport or film star. To someone not having the training and experience, the making of such an accurate picture would take hours and hours of planning and trying. Similarly, over the years a foreman gains a planning skill and makes his plans pretty much by rule of thumb, but still on quite an accurate basis. Furthermore, the informality does not mean lack of foresightedness and care. The processing method may very well be decided on during a lunch hour conversation when the boss and two or three foremen sit together. The conversation centers around shop problems most of the time, and it may sound something like this: "Say, boss, how do you want me to run job *x*?" "I thought that the cam should be run in three operations: drill, tap, and slot on a milling machine." One foreman might suggest that it would be easier to make the slot first and drill and tap later. Another might remark that if the cam were slotted first, the two lips might move a bit and it might be difficult to drill a perfectly straight hole. This would make the assembly work more difficult and more time consuming. Finally, the boss and foremen agree on what they think is the best processing method. They might then agree on the number of extra pieces which must be produced at each work station to make sure that the company ends up with the right number of pieces to make the shipment. Although all this is accomplished informally, it is nonetheless careful planning.

After lunch the foreman conceivably fills out the forms shown in Fig. 5-3. He uses the blueprint to find the name and number of the part. The quantity to be made, except for the surplus to cover the rejects, is generally known by the order size. The order number is assigned to orders as they arrive at the office. Then he takes other steps which culminate in orderly production.

Dispatching and Expediting. Since the small shop does not separate either dispatching or expediting from supervision, it is essential to discuss them as part of the supervisory work. Ordinarily dispatching initiates action. In the small shop, the supervisor checks the work load and decides which job will be run and by whom. When he tells the worker to start the job, dispatching has taken place. In large companies, dispatching entails other activities that are closely associated with the execution of the command: checking the availability of tools and special attachments, including jigs and fixtures, to be mounted on the machine; making sure that raw materials are available. In small shops, the foreman himself goes to the stockroom to check the raw materials and to the toolroom to see that the necessary tools are ready and in good working condition. He sees to it that the machines are set up and ready to go. In most cases, he helps in the setup work if the worker himself is not equipped to do it under his supervision. As a rule, the small-shop employee is more of the all-around man rather than the semiskilled man ordinarily employed by the large plant. Because the small-shop worker is more versatile, he commands a bit higher wage than the large-plant worker, despite the wage differential that results from the labor union activity customarily found to a greater degree in the large plant. Thus, the small-shop employee can set up his own machines, sharpen his own tools, get a replacement if necessary from the toolroom, and install the new tool in the holding device. In larger companies all these things are handled differently. Thus, in the small plant the dispatching function is in reality inseparable from job assignment.

What in large plants is called expediting may not be anything but control over employee performance. The fact is that the supervisor controls the flow of production by controlling the performance of the employee. Particularly in smaller shops, the expediting function is a minor problem because nothing can really get lost and employees and foremen can cooperate with one another to a greater extent than in large companies. Hence, the foreman does not, as a rule, lose sight of things; and he is able to keep track of production operations without the help of expeditors. When rush orders or special problems that arise in the shop demand an accelerated pace, it is the foreman himself who acts as the expeditor.

Generally speaking, foremen are familiar with each other's problems and can iron out difficulties themselves without much trouble. They do each other favors and in that way take care of problems which, in larger companies, call for expediting. The same thing is true of coordinating the arrival of material and the need for the materials, because the storeroom man readily cooperates with the supervisory personnel. All in all, the supervisors themselves can handle all the expediting work, and they can probably do so with a greater degree of success than the specialist expeditors in large business.

ACTIVATING IN SMALL PLANTS

Although the machine shop has been used to exemplify the small plant, it would be wrong to assume the discussion has no universal validity. Most small companies tend to be run in a similar manner. Some of them may be more complicated from the production point of view, but most of them are considerably simpler to manage and operate than the machine shop. Chemical, electroplating, bottling, and other small operations require pretty much the same kind of management skill and effort in process planning, production planning, and supervision as that described for a machine shop. That there is little or no separation between functional fields and that all decisions tend to originate with the owner and his foremen can be considered the main characteristics of small-shop management. An associated characteristic of small plants is that planning and decision making usually take place at or nearly at the same time.

Although to an observer planning and action in a small plant seem to be almost simultaneous, the mental processes involved are separable. The foreman might not sit in his office to plan things ahead, but he can be planning while he drives his car home in the evening. Planning has no "place" requirement; it need only precede command of action in the time sequence. Its main concern as far as small-plant management is concerned is that the work flow be so scheduled that interruptions are minimal and work does not pile up at any given work station. Particularly in plants of the continuous-flow variety, care must be taken that work stations are synchronized with one another in the sense that each station is able to absorb the work received from the preceding station. This may require the development of certain work standards, establishment of time limits, and elimination of unnecessary handling of materials and waste motions.

Once everything is properly planned, the next task of the foreman is to put the plans into action. As far as the supervisor is concerned this means selecting the employee best suited for a particular job. For extremely simple repetitive jobs, a person with relatively low mentality may be the best choice, but for jobs requiring skill and experience a more versatile workman must be found. Thus organizing requires the foreman to know his subordinate employees, their special abilities, skills, and shortcomings. A carefully developed job specification may facilitate the supervisor's organizing activity but, of course, in small plants this might only be registered in the mind of the foreman.

After the foreman has selected the right person for the job, his next duty is to direct the employee properly so that he knows what is expected of him. Direction is concerned primarily with explaining what must be done and how it must be done. In connection with this, it is much better to explain the job or the assignment and let the employee do it than to show the employee; explaining while the employee himself tries is of greater help. Direction requires an abundance of common sense and a rather delicate knowledge of good human relations. There is no simple rule for dealing with workers, because each worker is different. There is not one way, but there are many ways in which the foreman can approach the employee. The important thing is that the foreman get through to his subordinate. The language, the explanation, and the method of direction should, however, be suited to the mentality of the worker.

If possible, the supervisor should select the same worker for the same kind of job again and again. If performance reports are available, the supervisor can learn a great deal about employee skill from them. If the same employee is chosen for the same kind of job over and over again, repeated explanation can be avoided and the worker has a chance to become an expert on that job. It is essential, however, that at some time the worker get an adequate amount of instruction. This includes instruction not only on method but also on the dangers that may be involved. Safety must be a significant part of supervisory direction. Frequently, an inability to meet a production quota or produce an acceptable workpiece is the fault not of the employee but of his supervisor for failing to explain what should be done with the right hand and what should be done with the left at each moment of the work cycle. The employee must be told where the raw materials are to be deposited and where the tools must be kept so that wasted motions are kept to a minimum. Furthermore, it is of considerable importance that the foreman explain what he expects of the worker both in the qualitative and in the quantitative sense. Unless the employee is told what is expected of him, he is going to decide for himself what he will produce, and his idea of a good day's work is probably quite different than management's.

The control function can be exercised either through subtleties such as performance reports and wage incentives or by the highly personalized method of steady surveillance and checking or pushing the employee. It is in the interest of good supervision that the personal control which makes the work atmosphere unpleasant be kept at the absolute minimum. On the other hand, personal control through reward may be advisable; reward can be a tool of control in the same way that penalty can be. When reward is due, a good word and a kind remark can do a great deal of good, so long as it is sincere rather than phoney.

Generally speaking, however, the remote-control technique is somewhat better than highly personalized control because it creates an impression of freedom. Of course, control is there and the employee knows it; still, he does not feel its grip. It is always important to avoid personality clashes and the show of force, the show of authority. Authority is a very ticklish thing! Employees respond to it, but if it is not somewhat disguised, they tend to resent it and rebel against it. Furthermore, close personal control may have adverse effects on morale of the work team, and efficiency may suffer despite extensive control.

In speaking of remote control, one always implies the absence of visible means of control. The wage incentive is an excellent illustration. The boss may not be there and he may not see that an employee is relaxing on the job at company expense, yet the employee voluntarily avoids horseplay because he ultimately hurts his own paycheck when he hurts the company. Furthermore, deadlines based on careful time studies can indeed create an orderly but relaxed atmosphere and contribute to employee satisfaction and, ultimately, to production efficiency.

In good supervision, coordination of activities becomes practically unnecessary. A capable foreman should be able to develop goodwill, enthusiasm, and a feeling of belonging to the organization. If the foreman has succeeded in developing teamwork among his subordinates, coordination will be replaced by cooperation. Of course, it cannot be expected that perfect cooperation will be achieved. People will be people; one machine operator may dislike another and may not work easily or well with him. In such a case the foreman's task is to make the two operators cooperate by applying the pressure called coordination. Coordination is the final step leading to smooth production by a relatively perfect synchronization of all necessary activities to achieve the total task assigned to the supervisor. The problems of coordination occur more often in assembly jobs or in jobs such that one production phase depends on the other than in activities such that the employees do not depend on one another.

Supervisory success always depends on the teamwork of subordinates, and teamwork is but the end result of coordination and cooperation. The aim is to make people cooperate, and good supervisors can do that without effort. If the boss gives his subordinate foremen sufficient powers to carry out their duties, it is possible for them to achieve good results, whether they are liked or not, by the proper application of their authority.

The supervisory function is the key to any organization's success, and this is especially true in small business. It is frequently claimed that the supervisor can get results with sheer force in most small enterprises, but when the friendly relation between owner and employees lessens through company growth, the foreman cannot quite replace it. When employees no longer share management worries, their thoughts shift from the enterprise to themselves. Good scheduling and good production quotas can contribute to effective production, but slave-driving techniques cannot replace voluntary cooperation. Thus, it becomes essential in companies that are not quite small enough to maintain personal touch between owner and employees to use wage payment systems to raise the productivity of employees. The next section deals with the advisability of setting up wage incentive systems for the purpose of achieving smooth production flow and a high degree of small-business efficiency.

FUNCTION OF INCENTIVE PAYMENTS

Some authors claim that the function of wage incentives, including piecework payments, is to raise the productivity of workers above and beyond their capabilities. While such theories are psychologically sound, it stands to reason that contentment and satisfaction alone cannot raise production. Production can be raised by putting better tools and other facilitating devices into the hands of the worker or by carefully dividing the job to routine motions, and not just by making the worker happy. If that is true, what is the function of the wage incentive?

An incentive system is simply a method of assuring that employee output reaches company expectations. That output standards have been established on the basis of accurate time studies does not necessarily mean that employees are actually delivering the preset hourly output. As a matter of fact, in enterprises where no mechanical means exist to regulate the production pace and flow—and the small enterprise is usually one of these—production speed may well depend entirely on the goodwill of the employee. Some method must therefore be employed to regularize production. The methods described in preceding sections of this chapter indicate what management can do to regulate employee performance and production flow in the quantitative sense, yet most small shops face difficulties over production and productivity per man-hour of labor. The very small company can operate efficiently, but the company which operates with 30 to 40 employees may experience great difficulty in overcoming the apathy and lethargy of its employees. To counterbalance the general tendency to produce less than quota requirements, and thereby make certain that production schedules can be maintained without watchdog tactics, most small companies with vision establish some sort of incentive system.

The incentive system can, at best, make certain that the production quota is maintained. Through this system one does not get more work out of employees but does insure an amount which can comfortably be expected. Experience proves that, whatever we do, few employees will produce up to their full capacity without a financial inducement. Some sort of reward must be offered.

INCENTIVE DESIRABLE IN SMALL SHOP

If management schedules deliveries for a given date, it must deliver on that date. The customer is eager to receive the product and, of course, the supplier is eager to be paid. Small business tries very hard to deliver on time and be as reliable as possible. All these aims can be nullified by the irresponsibility of some employees. Thus, the small shop estimates the production cost per piece and turns over the work to employees with the promise that for each piece delivered the employee shall receive so much. The piece-rate type of payment is usually a sufficient incentive for workers to work harder. From the point of view of simplicity, it is the easiest method of wage incentive payment. Since employees are compensated not for putting 8 hours of their time at the disposal of the employer, but for workpieces delivered, most piece-rate workers work hard. The piece-rate type of wage payment more or less guarantees that employees perform to normal production capacity.

On the other hand, in companies where the workers are compensated by hourly wages, production scheduling seldom works out. It is, then, not every small shop, but the one paying hourly wages which experiences difficulties with production in the quantitative sense.

Labor unions, if present in the small plant, usually insist that workers receive hourly wage rates. If the small shop is unionized, its difficulty is magnified because management is not completely a master in its own plant. Labor unions insist on hourly rates because they want to protect the less efficient workers. The labor union contends that every worker, regardless of his native abilities, is entitled to a decent wage. Consequently, they fight the piece-rate system where it might lead to a reduction of income for a worker. Small companies, however, have to be efficient to stay alive, and the labor union is inclined to compromise by agreeing to a so-called incentive wage payment. The incentive wage payment is partly piece rate and partly hourly rate. In other words, those who produce above and beyond a quota will receive an added reward for the excess; nevertheless, everyone is guaranteed the hourly wage rate established for the particular job. This is a system by which the productive worker benefits while the inefficient worker is not penalized.

WAGE INCENTIVE CONSIDERATIONS

Small shops may experience greater difficulties with the incentive system than with the piece-rate system. For the small shop, obviously, production considerations decide which kind of payment is warranted. From the point of view of simplicity and ease of administration, hourly payment is advisable; and as long as the small shop is able to achieve the production requirement as well as meet delivery promises without overtime work, it should not deviate from hourly payment. But if, despite time studies and production control and performance control systems, it is impossible to make ends meet, recourse must be had to either the piece-rate or the incentive wage rate system.

While it is relatively easy to establish piece rates, it is more complicated to set up wage incentive systems. This is because a great deal of calculation is required; the time study data must be manipulated and the output must be recorded, tabulated, and computed. Most small businesses do not have the time and the breadth of knowledge to set up their own systems. If for reasons of efficiency a wage incentive system must be established, the best course is to engage a consultant to develop a suitable system which requires relatively little administration.

SUMMARY

Production in Small Shops.

Despite the common misconception that a large company is managed differently than a small company, it should be emphasized that a small production shop is little different than a large one: the same problems must be solved and the customary managerial functions must be carried out by someone. But because of its simpler organizational setup, the small company is usually not as *effectively* managed as the large one. Owing to a lack of extensive specialization among management personnel, those who plan the work must also carry it out. There is little, if any, distinction between line and staff activities, which indicates that small shops are pure line organizations. A line-and-staff organization evolves as a natural consequence of growth.

Special Small Shop Problems

Regardless of size, all companies fight for markets. The small company, like the large one, must supply what the customer wants. The customer wants two things: low prices and prompt deliveries. Because of their complicated and effective management organization and extensive mechanization, large companies tend to be more effective than small shops; nevertheless, small shops must compete with large ones on a price-cost basis. Smallness cannot be an excuse for inefficiency, and small shops must therefore capitalize on their inherent advantages of simplicity and informality. Large shops mechanize and put in conveyors with which they can regulate employee as well as company productivity. Despite labor union interference, large shops can therefore be both effective in the cost sense and productive in the quantitative sense. The small shop does not always find that extensive mechanization is feasible, but it has the advantage that it can operate without being organized by labor unions. For that reason it can regulate production and cost through a careful control over employee performances. To understand the difference, let us restate the problem of obtaining production efficiency:

Aim: Production Efficiency

Large Shop	Small Shop
Means:	Means:
Mechanization	Control over employee productivity
1. Conveyor belts	1. Supervision
2. Mechanically regulated pace	2. Wage incentives

Result: Low-cost operation

The large company solves the problem as indicated by the left-hand column, and the small company has the methods indicated in the right-hand column; yet the overall aim is always production efficiency.

MANAGING THE SMALL PLANT

The small-shop foreman is the key person in the production setup, and a lot depends on the skill of supervisory personnel. Since the small-shop foreman has no staff help, every problem must be solved by supervisory personnel. In large plants, there may be a score of planners; in the small plant, the foreman and the owner-manager must take care of all aspects of engineering planning, production planning, and other preliminary activities. Since they are trying to discharge five management functions, it often happens that neither planning nor supervision can be perfect. But despite its size and its lack of specialized management talents, the small shop must be nearly as efficient as the large one. Although informality characterizes the small shop, the fact remains that engineering plans must be set, production plans must be developed, and orders must be completed as promised. Usually no formal records are kept because those who are responsible for management keep the information in their heads. This works as long as size is small and competitive conditions are not too rough. When the profit squeeze is on, small businesses are usually put under extreme strain.

The main cause of strain is that memory does not work so well when every minute of machine utilization and employee production counts. When maximum value must be obtained from men and machine, memory is no longer an adequate guide. When delivery schedules must be met in order to break even, the company must handle larger volumes than before within the same amount of time; and tight scheduling and expediting of work then become necessary. Faulty estimates of operation times and sequences, laxities in supervision, errors in scheduling, and hurry-up campaigns can turn the small shop into a place where the owner can lose his shirt. Thus, the small shop must, despite unfavorable conditions, establish production systems which permit plant operations to be carried out with greater efficiency and a greater degree of regularity.

The small shop grows; growth means problems; and problems require solution. Planning the solution of more and more complex problems means the introduction of enough paper work to keep the production flow smooth. Though the characteristics of production do not change, certain aids are instituted to make the planning process as well as the supervision process more accurate and more suited to effective production. Note that the company still remains a line organization. The introduction of systems simply means that the small shop has accepted some of the methods of the larger shop but has kept the framework of the line organization. Guesses and mental juggling are replaced by systemization. Informal discussions among foremen and the owner are still the basis of planning, but the plan gets form by virtue of being written down.

The large plant controls production by forcing labor to assume the pace dictated by the conveyor and the production line; the small business must somehow get labor to produce without recourse to mechanical aids. Supervision and regimentation are the goal, and simple paper-work and time study systems are the vehicles.

IMPROVING SMALL-PLANT OPERATIONS

First of all, routing and processing must be formalized. A simple route sheet containing job information must be established. The route sheet, when made out in duplicate, does several things: 1) it formalizes operation sequences, 2) it contains information needed by supervisors and workers, and 3) it facilitates scheduling and expedites production activities. The reader should remember that the route sheet and job card are combined. By tearing off job slips (job cards), the next step is made evident and it can be seen how much more work is still to be done on the job. One copy of the route sheet must go with the job; the other copy is used by supervisors for planning purposes.

Scheduling can be done on a pegboard, a simple device consisting of two rows of nails. One row on the pegboard shows how much work is waiting for each machine, and the other row shows what jobs are on hand at the moment. Each machine is represented by one nail in each row. An operation is allocated to a particular machine simply by tearing off the job slip and pinning it on the pegboard. To facilitate expediting and to keep track of his men more effectively, the foreman must make notations on a blackboard. This means that he must know the time required to perform an operation and, in turn, requires that time studies be made with the help of a stopwatch as soon as a new operation has started or before it is in the pilot stage of production.

While systems make production easier in the planning sense, they make control over employee performance more difficult in the human sense. However, small-shop efficiency requires that both planning and executing be done so that production flow is steady (even though production is itself intermittent), and equipment utilization is perfect. If equipment is fully utilized, labor productivity has also been enhanced. Men and equipment go hand in hand in small business, and a successful control over the one brings a successful control over the other. Thus, efficiency results from good supervision and from an intelligent use of planning tools by supervisors.

Supervision, however, is more than good planning. The small-shop supervisor can be effective through good planning only when he succeeds in putting his plans into practice. To succeed, he must properly direct the employees at the time he makes the job assignments. Before that, he must pick the right man for the right job and, above all, win the worker's confidence. This is a matter of human relations based on common sense and some knowledge of psychology. Proper selection of men and proper job assignment and instruction tend to result in good performance. Neither precludes further controlling activities, and, indeed, it is essential that the foreman follow up to achieve both qualitative and quantitative performance in the time unit established by time study.

QUESTIONS

5-1. What is the difference, if any, between small production enterprises and large ones?

5-2. What are the main characteristics of the small shop?

5-3. How much management specialization can we find in small production enterprises?

5-4. What are the functions of a production foreman in the small company?

5-5. In what kind of business is the typical small shop engaged?

5-6. What is the importance of small business in the national economy?

5-7. Who carries out the engineering planning function in a small company?

5-8. Whose responsibility is the production planning and control in small plants?

5-9. How is production planning carried out in a typical small company?

5-10. If the size of the company warrants a paper-work system, what kind of paper work is advisable?

5-11. Are time studies necessary in a small shop?

5-12. Why is it expedient in small plants to make a hurried time study rather than a careful one which gives proper allowance for fatigue, delays, and other measurable elements?

5-13. How can a small shop exercise a better control over employee performance than a large enterprise can?

5-14. What is the function of the pegboard?

5-15. Why are human relations important in the supervision of production activities in small shops?

PROJECTS

5-1. Suppose that you contemplate establishing a small company. Determine the type of production in which you could profitably engage. Determine subsequently how you would run the affairs of the company and indicate in a comprehensive report how you would ensure that production would result in profitable operations.

5-2. Compare two plants with which you are familiar. Choose one small plant which is engaged in continuous production (for example, a bottling company) and another in intermittent production. a) List the similarities found in these companies as far as management is concerned. b) List the differences found in these companies relative to managerial work.

5-3. Design a paper-work system to control production for the two companies discussed in Project 2 and explain how your system could increase the efficiency of the operations. If the company in question has a production control system, examine and criticize it.

5-4. Explain how you would carry out a time study project in a small intermittent-production plant repairing electric motors.

5-5. Develop incentive and production control systems to enable management to exercise control over production in the small plant of Project 4.

CASES

5-1. The Mahogany Furniture Company

The Mahogany Furniture Company manufactures high-quality furniture sold to wealthy people through retail outlets but built to customer specifications. Thus, for instance, one customer might ask in a retail store for a copy of a seventeenth-century furniture set as used in France during the reign of Louis XIV. He might have a picture or the design itself. Another customer might take an antique furniture piece to a store with the request that a replica be made of it or that a set of furniture be made in the same style. Manufacture of the furniture is accordingly based on a design given to the company or produced to specification by company designers. The designs are turned over to the various foremen, who make all the production decisions.

The Mahogany Furniture Company is located in a two-story building in Los Angeles, California. It has an excellent hillside location. Both the first and the second floor are accessible to trucks. Receiving, kiln-drying, and millwork are on the second floor; cabinetwork (that is, assembly; see the accompanying illustration), finishing, and shipping are on the first floor. Parts are transported by a gravity roll conveyor from the second to the first floor, where they are assembled and finished. The plant layout is based on the functional principle.

The company was founded by a Japanese carpenter and cabinetmaker in 1924 to serve the needs of film stars who wanted exquisite furniture. He named the company as he did because at the time mahogany was the most

Assembly-line manufacture of break front chinas. (Courtesy of Bassett Furniture Industries.)

popular furniture. With the passage of time, however, people associated the company name with good furniture of all kinds.

The company prospered in its early years under the able management and superb craftsmanship of Mr. Yamamoto. Through the reinvestment of profits the business grew into a sizable enterprise. In 1958 Yamamoto, Sr. retired and his son Joe, a graduate of the University of Southern California, took over the management of the company. Although college-educated, he was, like his father, an excellent cabinetmaker. The elder Yamamoto had seen to it that his children had earned their position in the shop, and all his children knew a great deal about the furniture business.

At the time Yamamoto, Jr. took over the management, the demand for high-class furniture had increased to such a degree that production could hardly keep up with it. This was true despite the high prices charged by the Mahogany Furniture Company.

The company was engaged in the construction of both solid and veneered furniture. Solid construction refers to furniture made of high-grade wood which lends itself to carving; veneered construction is considerably harder to form. Unless curvatures of unusual difficulty were required, most furniture of the Mahogany Furniture Company were veneered. Generally speaking, veneered furniture is more durable than solid construction. In view of the price, quality, plus durability, were important considerations to the purchaser of high-class furniture. A veneered panel, for instance, is nearly twice as strong as a solid-wood panel of the same thickness.

Although the furniture business was excellent during the two decades following World War II, neither of the Yamamotos increased the number of employees beyond the present 39 skilled craftsmen. Instead, multicarvers, multicutters, and other mass-production devices were installed to replace hand tools and simple machinery. Despite an added degree of mechanization, the company still was and remained an intermittent-job shop; nevertheless, multicarvers and other mass-production devices became of increasingly greater importance as demand for the company's products grew. Although the company refused to expand its labor force, it increased its productive capacity by means of mechanical carving and cutting devices. Mechanization solved many problems, because a multicarver, to mention one example, could multiply production without adding to labor time. A multicarver with twelve cutting heads directed from a central lever guide could carve twelve identical workpieces placed in frames. Thus, only one skilled carver was needed but productivity was raised twelvefold. Similarly, multiple-cutting-head equipment and automatic lathes and shapers capable of multiplying output per man-hour of labor were installed. Without adding to the work force, then, the acquisition of new equipment enabled production of more parts with fewer men in less time. Although the overhead costs increased substantially, the company was now more profitable, because of productivity increases, than ever before in its history. Through mechanization the company could keep up with the growing demand without sacrificing craftsmanship. Where operations required little artistic skill, men were gradually replaced by equipment such as cutoff saws, ripsaws, double planners, molders, double tenoners, glue jointers, shapers, cutters, stroke sanders, drum sanders, and hollow-chisel mortisers. Extensive mechanization made possible greater productivity, although some people in the furniture business think that using multicarvers deteriorates furniture quality. In a sense, however, the opposite is true. The multihead carver guided by a highly skilled carver shapes all pieces simultaneously and therefore produces identical parts.

Recently, new policy resulted from an error. By a mistake in the shop order and by means of the multicarver, two identical sets of bedroom furniture were produced. When the error was discovered, both sets of furniture were almost completed. The question was what to do with the extra set. Finally, a leading out-of-town furniture store purchased it at a relatively high price. Mr. Yamamoto, Jr. thereafter made it a policy always to produce as many furniture parts as the multicarver could handle. The idea was to utilize machine capacity up to 100% although there were no immediate customers for the extra furniture. From an error a successful company practice evolved. Out-of-town dealers were eager to make cash purchases for any custom-made furniture. Although they did not pay the original customer's price, the financial arrangement was very lucrative to the Mahogany Furniture Company. Since the product was sold not in Los Angeles but in other markets, customers never knew that, somewhere in the United States, there was a duplicate set. Thus, the company started to produce a limited number of stock items. Since the company got greater production from the carving equipment, in addition to getting substantially more work per unit of time from the carver (a high-paid craftsman), it could afford to sell the extras at a lower price and still make a substantial profit. Unit cost on the "seconds," as the company called them, were negligible, since both the tool-up and craftsman's time were fully paid by the original customer. Labor cost per unit of output in the assembly and finishing departments was of course unchanged, and so was the cost per output unit of kiln-drying. Carving time prorated to unit of output, however, was significantly reduced, and it is mainly the carving that runs up production costs of custom furniture.

But the tremendous success with seconds put an almost impossible difficulty in the way of execution. The kiln-drying department could barely handle the increased work load. Although production capacity was sufficient, the drying process could not very well be speeded up. Any attempt to do so would create a quality problem. But despite warnings from the foreman of the kiln-drying department, production was stepped up. Overtime work was instituted and employees in kiln-drying worked an additional 2 to 3 hours per day. Although this increased labor cost on the overtime portion of the workday by 50%, profit margins were sufficiently high to warrant the added expense.

From kiln-drying, where the moisture content of the lumber was reduced to approximately 6%, the lumber went to millwork, where the rough lumber was shaped and formed into furniture parts. When millwork ran out of raw materials, the departmental foreman went to see the foreman of kiln-drying and expressed an immediate need for workable lumber. Since it was the responsibility of every department foreman that the next department was supplied, the kiln-drying foreman did everything in his power to supply the needed seasoned lumber. On the whole, the production on the second floor (accessible to trucks, on the hilltop) was considered efficient. The foremen involved cooperated with one another quite well.

As a rule, Mr. Joe Yamamoto told foremen when he wanted to make his shipments and they were always able to meet his deadlines. Although the foreman of the kiln-drying department opposed the hurry-up campaign, production goals were attained.

From millwork, furniture parts went unidentified to the cabinet work (that is, assembly department), where in the past the foreman and employees had always been able to identify by sight every part belonging to any given chair, bed, or dresser. Now that the production volume had more than quadrupled, though, confusion was not unusual. Parts got mixed up and were even lost occasionally. To replace them, new parts had to be made in millwork. Double work, both in the millwork and in kiln-drying, further added to the greatly increased work load, thereby creating problems of magnitude in addition to confusion in general. Although everybody agreed that some sort of identification system was now needed, the attitude of production employees and the foreman was that, "If we did things well in the past without gimmicks, we can do them now too." The employees of the company were loyal and proud, but they were annoyed by the prospect that new employees, new skills, and new systems might be considered. If overtime work was considered, they were the ones who wanted to get it. There was no slowdown, however, to force management to overtime work. Everybody worked hard to meet schedules as determined by Mr. Joe Yamamoto on the basis of the various delivery promises. Although Mr. Yamamoto did not use any scientific procedure, he could tell when the plant could ship any given order by simply looking at the backlog of orders. So far, this method had worked well.

About eight months after the production of seconds began, difficulties were experienced by both the kiln-drying department and cabinetwork. Some machined parts coming out of millwork were sadly out of tolerance, and it was often quite difficult to fit parts properly. When the millwork people were accused of producing defective parts, they shifted the blame to kiln-drying. Finally, it was found that although the overall moisture content of the lumber had been reduced to 6% by the speeded-up drying process, in the middle, as opposed to the surface, it was still 10 to 12%. After delivery of the lumber to other departments, the moisture content continued to diminish through a natural drying process and many parts got out of tolerance.

Something else began to happen: customers for both the originals and the seconds started to complain. Furniture was frequently returned because tables were unstable, table tops were wavy, drawers were sticky, joints had gaped, or surfaces had cracked. It was immediately recognized that all the returned furniture had a common fault: excessive speed in kiln-drying. The problem was recognized and efforts were made to correct it, but the losses for free rework were quite substantial and the publicity was bad.

Some customers canceled their orders, which created a great deal of confusion in millwork, especially when parts were in different stages of completion. Half-finished parts of nonstandard furniture models were worthless, of course. To avoid total loss of money already invested in these parts, the company decided to finish all orders, even though canceled, in the hope of finding customers for them by selling the furniture on the open market. Although a loss was involved, it was better to finish the furniture and save what could be saved than to junk the valuable parts.

The trouble was now quite obvious, but it was pointless to say that the company should have stayed out of making and selling seconds when the profitability of the move had seemed beyond doubt. The basic problem was that the company began production on a large scale but retained small-scale production methods. Despite mechanization, production was still based on craftsmanship. The use of multispindle and multicutting devices did not make the custom-furniture company into a large-scale producer. The foreman of millwork insisted that there was just not enough equipment to handle the multiplicity of orders. Mr. Yamamoto, Jr., however, insisted that equipment as measured in output capacity was sufficient, but that the foremen were incapable of utilizing available machine time properly. Of course, he might have been right.

Whatever the reason, both money and customer goodwill had been lost. As a direct effect, two foremen were fired. Mr. Yamamoto, Jr. claimed that they were purposely trying to ruin him, but production did not improve upon hiring two new foremen. As a matter of fact, production went from bad to worse, because some of the employees who sympathized with the recently discharged foremen lost interest in production. Thus, the two new foremen were unable to get employee cooperation to attain a high rate of production.

After several months of unsuccessful attempts to remedy the situation and correct the errors, Mr. Yamamoto, Jr. discovered that the problem did not lie after all in the two foremen, but instead lay mainly in the changing nature of the company's manufacturing activities. The prevalence of uncontrolled in-process inventory, as indicated by piles and piles of partially completed parts in millwork; the absence of records of the whereabouts of orders before delivery in cabinetwork; the frequency of rush orders given by millwork to kiln-drying; and the constant pressure for production created confusion and disorder with which management could not cope. When Mr. Yamamoto, Jr. realized the gravity of the situation and admitted that he was wrong about his original foremen, he apologized to them and rehired them with pay for the time they had lost. Thus, he ended up with six foremen. The two recently hired supervisors were retained and assigned as assistant foremen in cabinet work and millwork, respectively.

New production methods were installed. The assistant foremen acted more or less as chasers; their duty was to make sure that the products moved through the plant according to schedule and without damaging hurry-ups and also to see to it that piecemeal production was eliminated. They had to make certain that all necessary furniture parts reached the cabinetwork in time to prevent delays in assembly and that bottlenecks in production did not develop. But despite their sincere efforts, production did not function as well as it formerly had. Although the sequence of operations was more or less fixed, foremen sometimes performed operations out of phase. This was highly irregular and was done for the simple reason that certain types of machines were busy but others could be used because they were free. The battle cry was, "Get on the machine while you can." This resulted in an irregular and uneven flow of parts throughout millwork. When parts did not arrive at cabinetwork in time, the foremen of cabinetwork decided to produce something else to keep employees and equipment busy. Actually, this arrangement resulted in two unusual problems: 1) failure to meet some important delivery commitments on time and 2) completion of some other orders ahead of time. That the latter created a serious storage problem goes without saying. During storage time, polish and surface finishes were frequently damaged or scratched. Thus, it was not unusual that furniture pieces had to be refinished. Not only was there duplication of effort, but refinishing of completed furniture was more difficult than finishing it in the normal course of events.

Questions. The students should be reminded that several periods are involved and each development period has its own problems. However, each problem is related to the other in one way or another.

1. List the symptoms that indicate that something was wrong with the Mahogany Furniture Company.
2. List the factors, by period, responsible for the symptoms of Question 1.
3. Suggest methods of eliminating the causes listed in Question 2.
4. What was the major error committed by the Mahogany Furniture Company?
5. Do you agree with the company's decision to remain a small company?
6. Was the decision to mechanize instead of hire new craftsmen a good one? Why or why not?
7. Since the company was profitable with the production of seconds along with the originals, do you agree with Yamamoto, Jr. or Yamamoto, Sr.?

5-2. The Electronic Company (Part II)

This case is a continuation of the case history begun in Chapter 3. The production problems at the Electronic Company were numerous and resulted in costly production delays. The company's losing streak started with a multimillion dollar order and continued thereafter. At this point, the purpose is not to describe the overall company problems but to show how the company hoped, through the incentive system, to cope with some of the productivity problems at hand.

When a consultant analyzed the problems associated with production difficulties, he concluded that the main cause of trouble and financial loss was lack of labor productivity and consequent high labor costs. The latter was in turn due to failure on the part of the company to plan production systematically. Upon having this conclusion, executives of the company put their heads together and ask themselves whether labor productivity could be raised by employee cooperation and whether that would also solve the scheduling and cost problems. The solution was not simple. Experience indicated that even after a well-thought-out production control system with feasible production schedules was installed and even though standards were based on correct time studies, supervisory personnel were still unable to attain predetermined output levels.

After several months of unsuccessful attempts, management recognized the impossibility of increasing production with slave-driving techniques. Faced with an impasse, management recalled the consultant already familiar with the company for the purpose of setting up a suitable wage incentive system.

The plant superintendent explained to the consultant that the company failed to get employee cooperation and consequently failed to meet production commitments; the company's president complained that it seemed impossible to attain budgeted monthly production despite concentrated efforts. The consultant gathered the information necessary for his study (performance records, earnings in comparative companies, and time study data) and sometime later presented an incentive system. In his estimation his system would solve the production scheduling problem at the Electronic Company and would, at the same time, guarantee low-cost operations. Furthermore, the consultant contended that his system would also be highly satisfactory from the point of view of employees. It would accomplish its objective without the complicated administration ordinarily connected with incentive systems. This was a major selling point in favor of the proposed system, and after considerable discussion, Mr. Budelman, the owner of the company, approved the system.

The consultant based his system on the premise that production employees are not particularly interested in helping management create efficient production. He pointed out that Mr. Budelman had attempted several times, with little success, to get the cooperation of some of the older employees. The daily production report of the timekeeper indicated that the production quotas were generally met by the younger and newer employees; those who fell below production quotas were invariably men with high seniority, men on whose cooperation the owner counted most. Thus the company found itself in the predicament of reprimanding old employees with 10 to 15 years of service or abandoning the attempt to control production in the quantitative sense. However, the company felt that it could not afford either inefficient operation as in the past or the luxury of keeping on the payroll men and women who could not satisfy minimum output requirements.

This problem was apparent in the electrical assembly section. The sequence of operations was fixed and the production flow depended on every work station. Since the production line was perfectly balanced, the flow of production would have been continuous if every work station had performed as it was supposed to perform. Although a recently hired employee might have accomplished his share of the work, unless an old hand sitting beside him also performed as expected, production was delayed. Consequently, work piled up at certain work stations. If the operator next to a normally working employee did not work fast enough to absorb the work received, the neatly developed production line broke down. If only one old hand failed to work at the rate prescribed by the time standard, even those who were willing to work normally were forced to slow down. Psychologically speaking, it was difficult if not impossible to push employees when some "privileged characters" were purposely disregarding supervisory directives. An employee said, "I tried to meet production requirements, but others didn't seem to care. So I stopped caring myself." Situations of that kind caused the better employees to slow down also.

The production control system operated with only limited success because it was difficult to exercise control over employee performances. Although supervisors reprimanded workers who fell consistently below standard, the reprimands usually worked for only a few days, and then the employees started to be lax again.

The situation in the machine shop was somewhat different. Since nobody could hold up production in the sense that one operation depended entirely on another, results were more favorable than in the electrical assembly section. Even here those who frequently appeared on the deficiency list were older workers rather than newer ones. Thus, the superintendent came to the conclusion that the only sensible way to improve production was to lay off those who were frequently on the deficiency list under the pretext that there was no work for them. The system seemed to function. As soon as layoffs were announced, production quotas were invariably met by those who stayed on the job. The machine shop superintendent therefore made periodic use of this method. However, even it gave only temporary relief. A few days later, when they felt secure again, the employees started to fall below standard output requirements and production schedules were often delayed.

When production schedules were not met, management was forced to rely on overtime work to make up the loss in production. Overtime work, of course, meant increased labor costs and further deterioration of production efficiency. During his inquiry, the consultant learned that inefficiency was caused by the common knowledge of the penalty[2] clause in the government contract under which the company operated and the fact that the company had to make deliveries at the end of the month. Employees stretched the work at their first chance when they noticed that slave-driving methods were becoming prevalent. According to some employees who were cooperating with management, this was a sign that production was behind schedule. Since management seldom, if ever, fired anyone for not meeting production standards, workers could regulate their own income to some extent by regulating production. Overtime work was usually distributed according to seniority, and the old-timers usually got the extra income. Because old-timers were seldom if ever, fired, it would have been unfair to fire newcomers who occasionally also failed to meet production quotas. All in all, the consultant agreed with management's contention that only an incentive system could solve the problem of productivity.

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[2] Every day of delay in meeting commitments was penalized by a predetermined sum.

Before the consultant was ready to introduce the incentive system, he ascertained that all the prerequisite factors were worked out. Thus, for instance, he made it a point to see to it that the material control system fitted in and that the availability of raw materials was assured. When this was taken care of, he checked whether the production schedules were based on accurate time study. In the past, schedules might not have worked out because they were not based on accurate time study. The consultant stated that lack of production flow was not always caused by employee laziness or, for that matter, by slack supervision; it might have been due to handicaps beyond the control of workers or their supervisors such as shortage of parts and unreasonable work-load allocations.

For the purpose of the incentive system, the consultant divided the plant into the following groups:

1. Assembly of electrical appliances
2. Assembly of switchboards and wiring room
3. Machine shop (including weld shop)
4. Machine shop assembly (mechanical assembly)
5. Paint shop

The position of the service groups (stockroom and shipping and receiving) was a peculiar one that required special attention. While the service groups were important to the success of the company, in the consultant's opinion they did not lend themselves to individualized incentives. In other words, it was impossible to tie the stockroom activities to any kind of quantitative standard. Nevertheless, the stockroom could easily hold up production merely by not supplying the materials quickly enough, so that serious delays in production and losses in incentive earnings could be attributed to inefficient stockroom operations. Receiving could cause similar problems. Consequently, it was felt that these departments should also be entitled to a bonus.

Since one deals with a combination of group incentives and individual incentives, the distribution of the accruing bonus created conceptual problems. As far as the supporting service departments were concerned, it was decided that 1 per cent of the total bonus money accumulating in the five operating departments should go to the two service departments. The participation of service departments in the incentive system was desirable in order to gain the cooperation of everybody. It was essential, for instance, that materials would be handed out quickly and that materials handling would be in line with production requirements. The accumulation of money in the bonus fund also depended on shipping and billing. Thus, the shipping department was an important link in the production program.

Members of each of the five operating groups would, according to the plan, receive incentive bonus payments which would be based on the dollar equivalent of time saved. Because of the different nature of departmental activities, there were bound to be two different kinds of incentives. Assembly departments were to be compensated with group incentives, the machine shop people with individual incentives. In the latter instance, every job and operation had been time-studied. Although the various assembly departments also operated under a quota system, the output of these departments was measured when completed units were delivered. This was essential because certain subassembly operations could not be completely synchronized owing to possible difficulty with cables, wires, soldering, etc. However, operators could assist their neighbors as occasion arose. Furthermore, the counting of only the completed units would substantially facilitate the calculation of incentives earned by the group as a whole. It would also facilitate control, because if one group member failed to keep up with the rest, supervisors would immediately be notified by annoyed coworkers. Thus, despite difficulties with balancing the assembly line, work flow could be perfectly smoothed out without a conveyor system.

Output requirements after the incentive system was introduced were considerably higher than before despite the fact that standards were relaxed by 22% to serve as the incentive allowance. Accordingly, it was possible to earn 22% more for mere "normal performance." Every employee who met the standard (78% = 100%)[3] received only the regular rate. Those who surpassed standard requirements were compensated for that part of the output which was in excess of minimum requirements.

Let us assume that standard hourly output was set at 100 units per hour and that an employee produced 120 units of acceptable quality as determined by inspection. For the extra 20 units the employee was credited with a bonus for the time saved. If his hourly rate was $2 and he saved one-fifth of the allotted time, his incentive rate was $200 \div 5 = 40$ cents. The 40 cents was paid to the departmental bonus fund, although the bonus was earned by an individual. The psychology was that nobody would want to contribute less to the group fund than others, and management made use of this factor by posting the contributions of each of the workers to the group fund. Complaints to supervisors were frequent at the beginning, but they gradually fell off to no complaints at all.[4]

The departmental funds grew during a period of 60 days. After the sixtieth working day, the funds were closed and the accumulated money was divided among members of the bonus group. It should be emphasized that when the output did not meet quality requirements and was rejected, the bonus fund was charged with the labor-cost value of the rejected workpiece. Obviously, the company could not afford to pay for speed if it caused financial loss to the company.

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[3] 78=100 means that what is called 100% is in reality only 78% and it can be "beaten" by 22% by any qualified employee who puts in a "fair day's work." The production in excess of 100% (that is, 78% as far as management is concerned) is the basis of bonus pay.

[4] For the sake of accuracy it should be pointed out that the example is somewhat misleading because bonus earnings are split between management and labor. Thus, instead of 40 cents, the bonus fund would be credited with 20 cents only. This will be explained later.

Output was reported by the timekeeper, who counted it and determined the portion that required bonus payment. If surplus quantity was greater than the allowed reject, bonus was recorded; if not, a penalty was paid out of the bonus fund. An unexpected result was a reduction in the number of rejects. Although it did not amount to a great deal, it was a fortunate by-product with favorable effects on material as well as labor costs. Just who produced the reject did not make too much difference to the company, but employees insisted on identification of the workpieces to protect themselves against criticism by other members of the group.

Distribution of bonus funds every 60 days did not overburden the payroll department and allowed the accumulation of a sufficiently large amount of bonus payment for each employee to keep him happy. To an average employee it might mean a downpayment on a refrigerator; but if it had been paid with the weekly check, it would have been hardly noticeable. Also, during the accumulation period, the employees could talk in terms of large sums rather than a few dollars. The accumulated funds as posted on the bulletin board created amazingly great interest.

The system had its good points, but it also had its bad ones. Absenteeism was encouraged to some degree, but that was checked by group pressure. Labor turnover was reduced to almost none. Those who were fired or who left the company were excluded from bonus distribution unless their leaving was due to death, child-bearing, or an accident. In those instances, a bonus check was sent to the worker or his survivors. It should be mentioned that no labor union succeeded in organizing the employees of this company.

The money which had accumulated in the group fund was divided between management and labor on a 50:50 basis. Consequently, only one-half of the money accumulated in the fund went to employees. This kind of distribution of the total bonus fund left the two service departments with 2% of the total fund: 1% came from the workers' share of the group fund and 1% from management's share. Since success of productive efforts depended largely on the cooperation of the foremen, management's share was split between the company and its line supervisors. Had supervisory personnel not participated in the program, the success of the incentive system as a whole would have lacked supervisory support.

In the final analysis management gained 25% of labor time saved, in addition to better utilization of machinery, faster delivery of orders and elimination of penalty payments, better customer relations, elimination of overtime and Saturday work, and a greater degree of capital turnover.

Questions. This case is somewhat different from preceding cases. Here the general problem is presented and a program as it was put into operation is described. The task of the student is 1) to discover whether the small shop's production problems could have been solved without the wage incentive system and 2) to analyze the system to see whether it was based on proper principles. Although some of the results the system attained are also listed, the student should not be misled by them. It is conceivable that the results were coincidences and not attributable to the incentive system at all. Also, they might have resulted from the system, but not in the way expected by the consultant and the company.

1. What symptoms indicated that the Electronic Company needed an incentive system in order to cope with the production problem?
2. List beside the symptoms the causative factors and ascertain whether the causative factors could have been eliminated other than by the incentive system.
3. List your solution to the case:
   a. You can disagree with the consultant's system.
   b. You can suggest a system of your own. If you do, indicate why your system would have brought better results than the system proposed and installed ultimately by the consultant.
   c. You can disregard the wage incentive system altogether and show a method of supervision or production control which could have accomplished essentially the same results without the expense and bother of an incentive system.
4. What precipitated the recalling of the consultant and why could the company not cope with the situation without using the services of a consultant?
5. Is the situation which developed in the Electronic Company common to industrial enterprises?
6. What would be the difference between a proposed wage incentive system to solve the production problem in a) a canning company, b) a plastics producer's plant, c) a steel mill, and d) a coal mine?

5-3. The Gipsy-Cola Bottling Company

The Gipsy-Cola Bottling Company is both distributor and producer of soft drinks in a large Midwestern town. In the period of this case history, the company experienced difficulty in supplying the market during frequent summer hot spells, yet equipment stood idle for various reasons during many hours when either the expected consumption failed to materialize or when, owing to unwise allocation of employee time, work had not been done while time was available during slack business. When suddenly it was necessary to turn out soft drinks fast to meet an upsurge of demand, employees could not get to the important work because they first had to do preliminary work which had been neglected. Consequently, profitability was at stake.

The plant had a contract with the Gipsy-Cola Company to bottle and distribute Gipsy-Cola exclusively. The owner, Mr. Wenzel, was an ex-GI who, upon his return from the Korean War, invested all his family savings into the business. At first he rented the semiautomatic bottling machine with various attachments from the machine manufacturer. The understanding at the time was that the rental could be applied to the purchase price if the Gipsy-Cola Bottling Company stayed in business. Mr. Wenzel expected losses at first, but hoped that later they would turn into profits. After a while, when he had established contacts with grocery stores and with places where soft drinks were sold, business turned out to be better than he expected. During his first year of operation he made some profit which he invested in the purchase of the bottling machine, and he agreed to pay for the machine in 8 years. Costwise, however, he had 25 years to depreciate the value of the machine because the tax authorities valued the economic life of the equipment at 25 years. Since the equipment was expensive, his yearly installment payments, which had to come out of his business revenues, were very heavy.

The owner worked with his wife and retired father-in-law in the bottling plant. Better arrangements were foreseen, however, for the future. When the business had become established, Mr. Wenzel hired a few employees. As the demand for the soft drink increased, he added to his labor force, which currently numbers 17, including salesmen working on commission. The one-shift operation had been extended to two shifts and finally to three shifts.

Wenzel's bottling machine could fill 500 bottles per hour and his main interest was to make certain that the machine produced as steadily as possible. Although he has never succeeded, an attempt was made to run the bottling machine 24 hours a day during hot spells. It was, however, difficult to get that much production for various reasons. For instance, while the bottles were being washed or when demand was high, the plant often ran out of empty bottles and the filling operation was interrupted. Furthermore, it was not unusual that the soft drink syrup did not arrive in time. This was not the fault of the Gipsy-Cola Company, but happened mainly because syrup orders were not given fast enough. Owing to a shortage of cash, Mr. Wenzel did not pay his bills as promptly as he should have. If payment to the syrup producer was made in advance, the Gipsy-Cola Company shipped promptly, however. Inadequacy of working capital made it difficult to place orders so that the syrup shipment always arrived at the moment when production required it. The trouble was that grocery stores were slow in paying for the soft drinks. As a result of these problems, production was frequently delayed and downtime on the bottling machine was substantial. The employees monitoring the bottling process were consequently also idled. Although the owner could see this, he could do little about it because it was not entirely the fault of employees that they stopped working. However, the owner-manager contemplated the use of some sort of system whereby the employees would supervise themselves rather than need him always there to see to it that they worked. Actually, there was sufficient work but interest was low and the workers did not look for the jobs that had to be done. They tended to wait around until the boss came and told them what to do. Thus, jobs were not done which could have been done while business was slack. If a hot spell and high production came all of a sudden, jobs which were neglected had to be done simultaneously, thus holding up the rush work.

The situation was not so bad during the winter when demand was more or less uniform; but during the summer months, when demand on occasions exceeded capacity, every minute of production time was needed. By losing production time, the company could not produce as fast as it could sell. Profit could have been made had the Gipsy-Cola been already bottled and ready to go. Unless the company was able to make immediate shipment after the receipt of a phone call from a customer, the order was lost. Grocers and other retailers could always buy competing soft drinks. Thus, it was essential to keep a sufficient number of bottles on hand to meet spurts in demand. Once an order was refused for lack of available cases, the customer lost interest. To send a case of Gipsy-Cola within a day or two was not good enough, because by that time rainy weather might have eliminated the ultimate customers.

The general interruption of production was obviously serious. Demand could not be satisfied and profits were lost; more than that, while interruptions occurred, costs increased in proportion to the decrease in volume and sales went down. The installment payment on the bottling machine, the rent on the building, and the wages to employees still had to be met. It was not unusual that the plant could not cover expenses from current income and in addition, the owner himself had to go into the field to solicit business because two of his salesmen left. When he was too frequently in the field, his employees did not turn out as many bottles as machine capacity would warrant. It was very easy to check on employee output by comparing the number of bottles produced with the machine's maximum capacity. When the bottling machine was producing only about 50% of capacity, it was apparent that production was seriously defective. Lax supervision tended to add more and more to costs and to reduce earnings too. Bottling cost per unit was considerably higher than desirable.

Questions. The student should notice the difference between this case and the two others in this chapter. The Gipsy-Cola Bottling Company is a producer of one single standard item on a continuous basis. Although this is also a small business, its production and supervisory problems are somewhat different. Analyze the case just as the other case problems.

1. List the symptoms that something is wrong.
2. List the causes of the symptoms.
3. Suggest ways to eliminate the causes.
4. In general, what was wrong with the supervision of the company?

5. What should the owner have done to increase production and decrease his overall production costs?

6. Should he appoint one of his employees as a supervisor or could the problem be solved with better supervisory techniques placing a greater amount of responsibility on the workers?

7. If you were the owner, what would you do to solve the problems?

8. What managerial errors were committed at the Gipsy-Cola Bottling Company?

chapter 6

Process Planning for Intermittent Production

Processes and methods planning refer to those planning activities which are done by engineers, occasionally by industrial engineers. These activities precede production and can be considered as a prerequisite to actual production.

CHARACTERISTICS OF INTERMITTENT PRODUCTION

Intermittent production may simply be described as production of nonstandard items. Although the jobs are usually short-run and are undertaken only upon receipt of an order, this is not necessarily so. In any case, however, the producer makes the item to the customer's specification and the product is made individually rather than as part of a series. Examples of intermittent production are a specially designed racing car as opposed to an automobile of standard design and make, a custom-made suit as opposed to a ready-made one, a specially designed ocean liner as opposed to a standardized liberty ship, a specially designed and produced rifle as opposed to a standard one, a specially built boring machine as opposed to a standard piece of production equipment, an experimental amount of instant coffee mixture as opposed to a mixture already on the market. In other words, intermittent production means that a product produced once may never be produced again. It is conceivable, for example, that the air force might contract for a special satellite to be built by an independent producer and then repeat its order if the first one failed to go into orbit. Thus, intermittent production does not *preclude* further production of the same item. Nevertheless, the process of making items to order is commonly referred to as intermittent production.

PLANT LAYOUT AND MACHINERY

Although at this point we are not especially interested in product design, it is important to note that each intermittent-production order usually calls for a different design. It follows, therefore, that each new order requires that the product be designed by the company engineers or that the purchaser furnish the design drawing.

Since the design of each intermittently produced item is different, it is evident that each product is bound to go through a different production process. Thus, the process planning function must be performed over and over again as new orders are received. With notable exceptions, no two products go through the same production process, because the steps leading to the completion of two differently constructed items are almost certain to be different. A company engaged in the production of standard items arranges equipment in such a way that the production flow is continuous; the intermittent producer can do no such thing. If he did try to arrange his equipment for continuous flow, he would have to change his layout for each new order. If the student will recall that equipment is heavy and is usually bolted down or mounted on a special concrete base, he can readily see that plant layout is more or less fixed. Nor should it be forgotten that in a job shop, when new orders come in, the production of many earlier orders is still in progress. In other words, several orders are produced concurrently.

Different production processes, as a result of differences in product design, require versatile equipment. Therefore, a producer who continually makes different products cannot afford highly specialized equipment. In contrast to this, the producer of automobile motors can afford to buy a highly specialized machine that will drill, for instance, all the holes in an engine block simultaneously, but will do nothing else. An intermittent producer must purchase multipurpose drill presses or boring machines. This is similar to a decision about transportation which a small businessman might have to make. If he cannot afford both car and truck, he might buy a station wagon for use as a delivery truck and also as a passenger car.

Since intermittent producers, small or large, cannot cater to the production of any one item, they follow the functional principle of plant layout: all equipment to perform a particular kind of work is in a separate department. Thus there may be a milling department, a welding department, a drilling department, and a grinding department. If a given workpiece requires a milling operation, it must be transported to the milling department, where it will be assigned to one of the milling machines. Since the machine is usually a multipurpose one, it must be set up before it can perform the operation. "To set up" means simply to mount any necessary attachments on the machine and adjust the machine and attachments for the particular operation. The attachment may be a jig, gage or fixture, and it must often be specially designed for the operation. Although setup takes time, it is necessary to intermittent production.

Volume and Delivery Dates

Since production volume is small and since multipurpose machines must be torn down and set up for each operation, setup time may turn out to be quite substantial. It is the function of production planning to control the production flow in such a way that setup time is kept at a minimum. Some sort of waiting line which will enable an orderly flow, despite the recurrent use of the same equipment, must be developed. At this stage of our discussion we are not interested in how the production planning people develop an equitable distribution of work load to each machine, but we are interested in the fact that by using one machine for, say, ten different jobs, it is possible to get sufficiently good mileage out of production equipment to offset its depreciation charges. The setup is necessary if the same equipment is to be used for ten different jobs. The process people must remember that, by selecting a certain production process, production may be facilitated. If the production volume is relatively large, special machines and a special process can be selected more advantageously. By the same token, if delivery dates must be met, special equipment and a special set of attachments to the machine, that is, tools, gages, and fixtures, may be chosen because greater speed can be achieved with special, more suitable cutting tools or other attachments. It follows then that a relationship exists between tooling, processing, and setup. The latter adapts the equipment to different operations.

To summarize, the intermittent producer uses multipurpose (general purpose) rather than special-purpose equipment for the limited volume and multiplicity of product variety he handles. Because of the different product specifications, the arrangement of equipment on the shop floor cannot cater to the production of any specific item; thus, the intermittent job shop must use a layout which suits every product, not one in particular. Even though the plant layout must be such that the large majority of products flow as directly toward their completion as possible, it must be apparent that in such a plant layout backtracking cannot fully be eliminated. Because equipment will be "bunched," so to speak, in the sense that the same kind of equipment is located in the same department, we will have departments. The type of work the departmental facilities can perform in the functional sense (drill, grind, weld, mill, etc.) determines the name of the departments. Probably for this reason, this layout is called functional (or process) layout.

Since a production line cannot be built into the plant layout, it is necessary to establish for every order an *artificial production flow*. This is done subsequently by the production control department through "routing," which is based on the process sheet developed by the process engineers. More will be said about routing in Chapter 11. In light of these characteristics of intermittent production, let us now consider the processing problems which must be solved before allocation of available equipment among different uses can be made and production plans can be carried out.

PROCESS PLANNING

Effective utilization of plant facilities under the system of intermittent operations presupposes knowledge of production processes. Production planning cannot, therefore, start unless and until all technical problems are solved and the process (route) through which a product will move through the plant is established. This is where the production control department becomes operative. Specifically, the production control group must know which type of machine (not necessarily which particular machine) in which sequence must be used to perform the required productive steps on the work in process. Because the aforementioned problems are technical in nature, the process engineering department irons them out.

In order to establish the production process for a given item, the first thing the process engineer must know is: What is the item? Most products are a composite of several parts. Therefore, to get to the core of the problem, it is essential to break down the product into its component parts.

When the product is only on paper, in the form of a design drawing (blueprint), the very first step the process engineer must undertake is to study the blueprint and list the parts which make up the product at hand. The result is a bill of materials.

FUNCTION OF THE BILL OF MATERIALS

Production decisions are based on factual data, some of which can be found on the bill of materials. This list of major assemblies, subassemblies, components, paint, grease, and other elements which ultimately compose the product will aid in various production decisions. The production process, for instance, cannot very well be determined without availability of such a planning tool. While it is true that in many companies no one bothers to put into writing the list of assemblies and its component subassemblies and piece parts, such a list is always available—at least in the minds of those needing the information. Evidently, as long as planner and executor were one and the same person, it was not absolutely necessary to have a formal list. Nowadays, however, one staff department would not know what the other is doing without written information flow. In a sense, the bill of materials conveys certain information without which the work of another department cannot begin.

In process planning, often the same process engineer makes up the bill

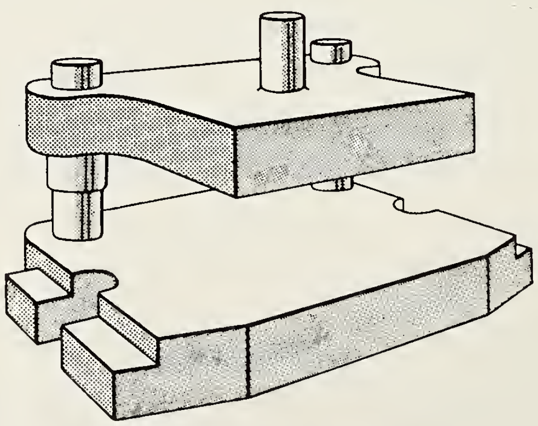


FIG. 6-1. Die set.

of materials and uses it. He takes the various items listed (disregarding those which are purchased on the outside) and develops a production process for each part.

Figure 6-1 shows a typical product made by job shops; it is a die set, which is ordered individually. (Die sets are special attachments on presses. A mass producer buys one according to his own specifications from a job shop engaged in this kind of manufacturing.) It is unusual to receive an order for a second die set of the same kind. At any rate, the customer will give the specification to the die set manufacturer as shown in Fig. 6-2. Now the preparation of the bill of materials requires listing the individual parts which make up such a set. Generally speaking, the blueprint will give not only the dimensional specifications but also the name and number of each component part. If no name or number is given, the process engineer dreams up a suitable name and a number for each component part. Name and number, particularly the

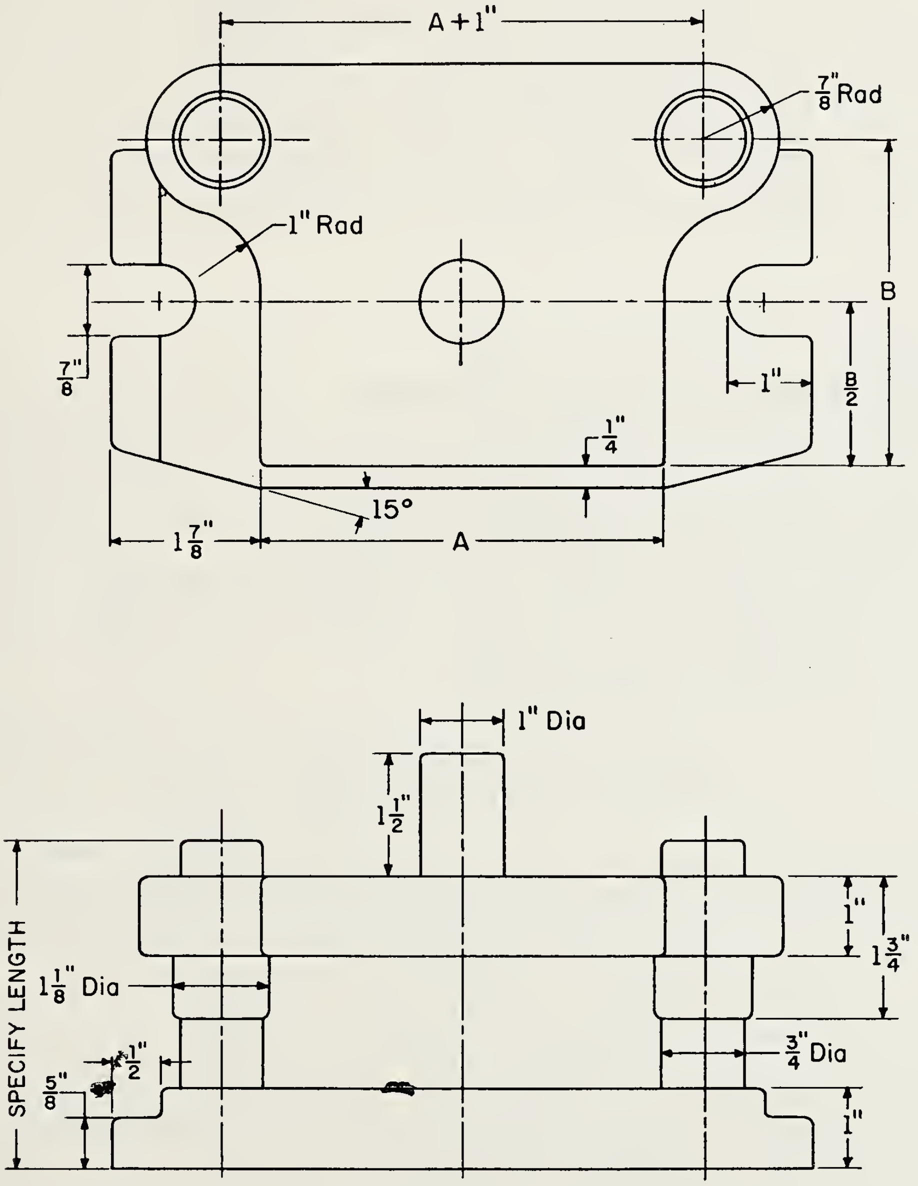


Fig. 6-2. Die-set specifications.

number, identifies a product in the process of production. If the product contains two identical parts, the name and number assigned to each part must be identical. As a rule, however, the name of the components and the number assigned to each component part or subassembly are written on the blueprint and the customer's identification will be used.

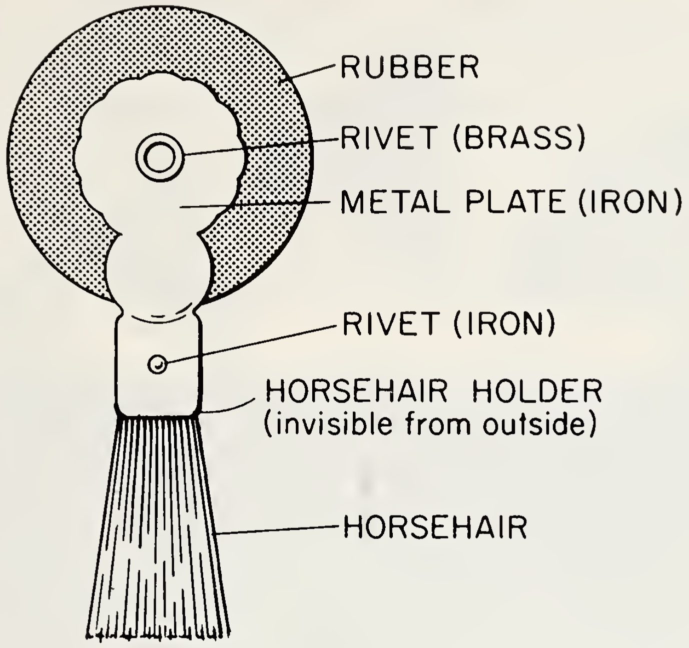
In the mechanical field we are concerned with parts fabrication and with the assembly thereof. After each part is completed, the various related parts are then assembled. These parts are listed in the final section of a bill of materials and, for this reason, it is often called a *parts list.* A bill of materials, however, is a bit more inclusive than a parts list because in addition to the parts it may show the major assemblies and the subassemblies which make up the product. From the production point of view, we are interested in the parts because a part is in itself the result of a production process; that is, it may have gone through a number of production operations before it was completed. Process planning determines how a raw material will be converted into a finished part.

PROCESS SHEET

The bill of materials lists all components of an item, those made by the company and those purchased from a vendor. The purchased items are of no interest to the process planner but the parts made by the company are carefully studied by the process engineer to determine how to process them. In making the eraser depicted in Fig. 6-3, the fabrication process of the two metal parts must be established first, then the assembly of the rubber part, the metal plates, and the horsehair brush follows.

Since products are made step by step (each step changes the item a little bit until finally the material assumes the shape and form specified on the drawing), it is essential to know that each step precipitates the use of different equipment, or the same equipment with a different setup. Figure 6-4 excellently illustrates that even a simple item, say, a pen point, takes 51 to 55 steps before it is ready to be assembled with the pen itself. The material is transported from machine to machine until finished.

After the design is approved, the process engineer goes over the job to determine the necessary production steps and the specific sequence in which they must be performed. This sequence follows a rather logical pattern. As this information is recorded on a sheet of paper, a *process sheet* is being created. The process engineer, or whoever is capable of determining the productive steps needed, sees the drawing (blueprint) of each part listed on the bill of materials or on the parts list. Each part must itself be processed before it can be of use in assembly. If the production process involves metal or machine parts, it is easy to see what must be done; but if chemical operations are involved, what has to be done becomes less obvious. Take batch production of a synthetic. Before the chemical ingredients are turned into a chemical



Bill of Materials (Parts List)

Number in Unit	Name of Item:	Part Number	Make	Name of Vendor, If Vendor Item
1	Rubber (eraser)	454		Goodyear
2	Metal plates (iron)	221	Yes	
1	Rivet (brass)	134		National Rivet
1	Round-head rivet (iron)	122		National Rivet
30	Horsehair brush	---		Nebit Brothers
1	Horsehair holder (brass)		Yes	

Fig. 6-3. Eraser and its bill of materials.

product or synthetic, they must go through several operations. Each step takes place inside of a container or tank into which the chemicals are poured via pipes; these steps are not visible. Chemical changes take place within these tanks as a result of temperature, pressure, or other operational changes. As illustrated in Fig. 6-5, employees merely regulate the gages and instruments and allow the chemical ingredients to flow into or out of the tanks.

The sequence in which each operation takes place is of special importance. As a rule, certain operations must precede others, just as socks must be put on before shoes. In other instances, the operation sequences are interchangeable. But even when operation sequences are interchangeable, it may be faster and more economical to run the job in a certain sequence. Thus, it may be immaterial whether the side, top, or bottom of a workpiece is milled first, but it is important that rough milling should precede finished milling. The function of process engineering is to determine and record on the process sheet the sequence of operations such as bending, milling, drilling,

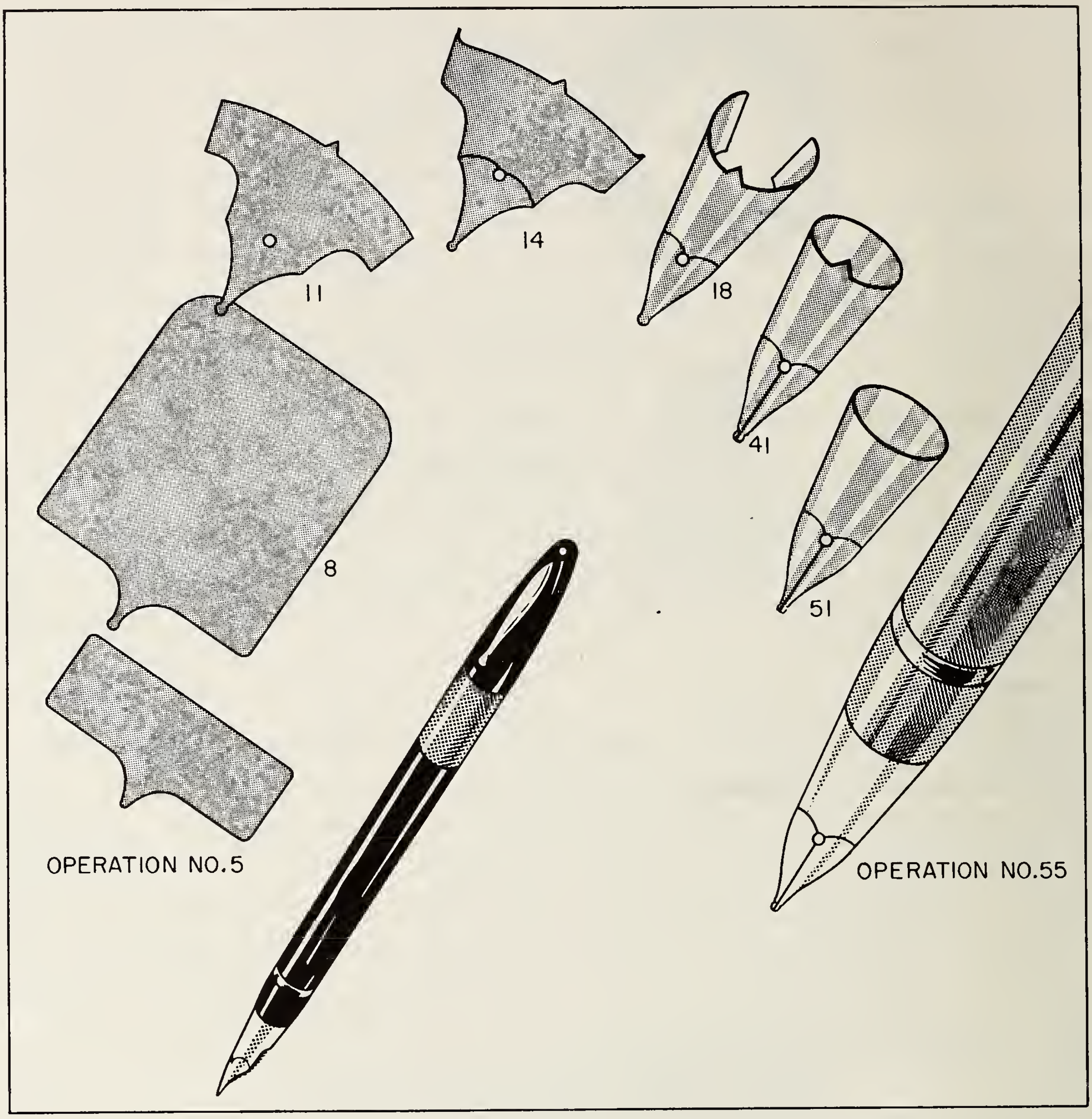


FIG. 6-4. A pen point for a fountain pen as it appears at various stages in manufacture. In all, fifty-five operations are necessary. (Courtesy of W. A. Sheaffer Pen Co.)

reaming, countersinking, and buffing which must be done on a given workpiece as it advances step by step toward its completion.

It is also necessary to record the jigs, fixtures, or gages needed at each work station. This information must be listed along with the various operations. This is typical, however, only in machine shop type operations. Furthermore, the process engineer must determine technical problems such as feeds and speeds at which the machine can be run without damaging either the workpiece at hand or the machine itself. The feeds and speed at which the machine can be operated depend primarily on the physical properties of the material and the required quality.

It is customary to show on the process sheet not only the operations but also the point where inspection is necessary. The process sheet furthermore must list the type of machine capable of performing the various operations. The process engineer does not state which particular drill press should do the job but only notes that the operation in question requires the use of a drill press. It is then up to the router to decide which drill press should be used. However, if bending, for instance, is necessary, the process engineer must state whether the task requires a 50-ton, 80-ton, or even heavier press and whether the bending operation must be done in stages, such as first bending, 20°; second bending, 45°; third bending, 80°; and so forth until the desired shape is reached. Obviously, such decisions require technical knowledge. If we want to bend a metal plate, it is essential to know, in addition to the mechanical capabilities of the equipment, how much bending the specific gage and type of metal can take without breaking or cracking. By knowing the properties of the metal (workability, hardness, high or low grade steel or alloy) and the capability of the equipment, the process engineer can accurately determine how many operations make up the production process of bending a specific workpiece.

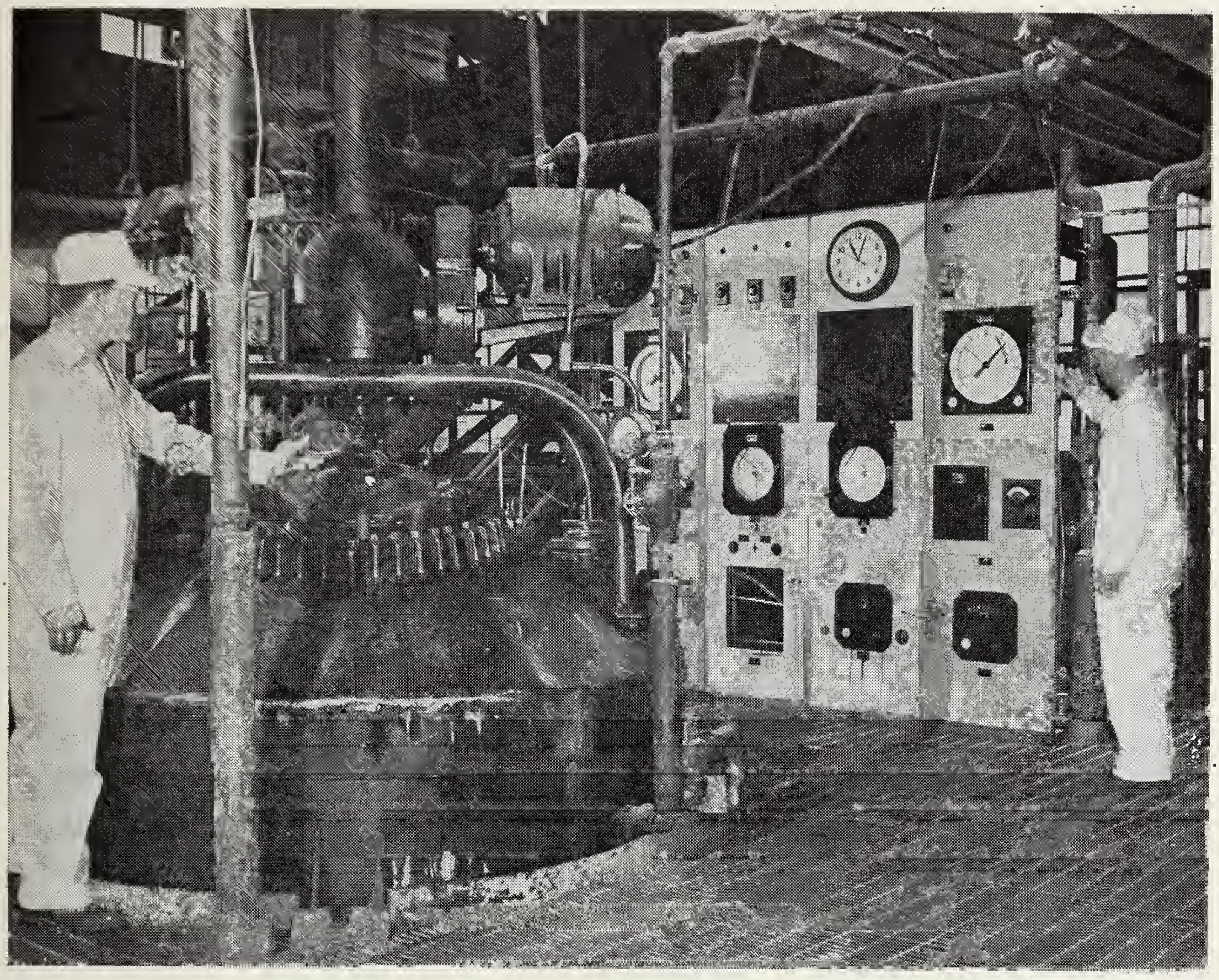


FIG. 6-5. A typical chemical operation. (Courtesy of the Dow Chemical Co.)

At this stage the process engineer deals only with the drawings; the product is in the form of a blueprint. The engineer must study the specific blueprint of each part of the product and on the basis of the information contained as to dimensions, ± tolerance requirements, qualitative or other specifications, he must decide how the part in question should be processed in the shop.

PROCESSING KNOW-HOW

No process engineer is worth his salt unless he is capable of making both technically-correct and economically-wise processing decisions. Just as designers have a free choice with respect to practicality, functionality, and other design considerations, so the process engineer must wade through a large array of processing considerations. Although there are many good methods of accomplishing the desired ends, the difficulty lies in picking the best method from the standpoints of cost, technical perfection, and equipment limitations. Accordingly, preparation of the process sheet requires serious decisions not only in respect to the product, but also to the limitations of available equipment and qualitative considerations. Although technical perfection is desirable, the method that is technically best is frequently abandoned because either the production cost, processing time, or some other technical or nontechnical considerations would conflict with company financial or delivery policies.

Process development starts, of course, on the drawing board in the sense that designers tend to think in terms of production. The design is usually the result of many conflicting and interacting technical, financial, and other relevant considerations and it is the most practical choice under the prevailing circumstances. Nevertheless, one of the most provocative of the many considerations in design work is *producibility* at low cost. Thus, ease and practicality of processing is *designed* right into the product. That a constant communication between the customer, the design engineer, and the process engineer takes place is quite understandable. Such perfect cooperation between interested parties in intermittent production is less apt to occur than is mass production. In intermittent production, the design is usually supplied by the purchaser, who wants the manufacturer to produce the item according to his specifications. In that case, whatever the design is, the company's process engineer must decide which steps must be taken to build the required qualities and specifications into the product at hand.

Although the design drawing does not indicate the most suitable production method, a given material lends itself to only a limited number of production methods. Also, the production specifications of the customer must be taken into consideration. These are shown on the design drawing and will have a definite effect on the nature of the fabricating method. To a man experienced in production and engineering, the drawing reveals a great deal about possible production methods. The design drawing shows designated shapes and forms. The raw material has properties that determine, for example, whether it can be bent or must be drawn, stretched, or rolled. Any machining specifications such as interchangeability and tolerance more or less fix the kind of machining operations needed. Although we speak here about properties of metals, the student should be aware that plastics, glass, and other materials involve similar considerations. While raw materials and production processes may differ, the thinking and decision-making processes are similar, if not identical.

The required operations and their sequence are simple decisions for a technically trained man. The functional requirements of the product and the physical properties of materials are the determining factors in both raw-material selection and process planning. For example, should the raw material be a casting or a forging? The process planner will know about the hardness of a forging as opposed to that of a casting. Or would a bar stock be even better? If, from the point of view of processing, a casting is the advisable raw material, the question of whether the casting was made in sand, a die, or a metal mold will precipitate various processing considerations. The process planner will immediately think of the number of steps and specific production equipment required by each of the raw materials considered. He will know that a sand cast requires many more machining operations than a die cast. At the same time he will be aware that a sand cast is less expensive than a die cast because only low melting metals lend themselves to diecasting. He will also know that he can save on machining operations by using a die cast. Thus, he will compare costs and other factors and will finally decide on the most suitable operation under the prevailing shop conditions.

To summarize, a certain design implies certain raw materials. Design and raw materials in turn place limits on the processes that can be used. The processes in turn imply the use of certain machinery. Thus, knowledge of production steps, of properties of materials, of alternative processes, and of production costs of different processes, together with much other technical know-how, is prerequisite to good process engineering.

Basic Facts About Production Processes

It is beyond the scope of this book to give elaborate details about the various production processes. To begin with, it is unnecessary to know why an engineer chooses one operation rather than another. Nevertheless, it is worth pointing out that each type of operation goes hand in hand with certain technical or other production limitations and advantages that depend on the material or equipment used. For our purposes we ought to know that a certain type of material can be processed with a certain type of equipment. Furthermore, we ought to know that capacity of equipment is affected by the nature of the material being used and processed and the degree of accuracy that is required. That the volume which must be turned out will influence the depth of tooling and the methods selected to process the product seems to be a rather logical deduction.

As an example that may give an insight into the difficulties which a process engineer faces in deciding on the proper process, let us consider welding. It is essential that the welding temperature which the available equipment can produce be sufficiently high to melt the metal of both parts to be joined. If the equipment cannot produce the required temperature, the welding method cannot be considered. How much pressure the machine can exert is part of the same decision; the pressure must be sufficient to hold the adjoining parts until the junction point cools off and hardens. Thus, the process decision will rest on the engineer's experience and such basic considerations as welding temperature and time of cooling.

Though a technically trained man might have knowledge about various materials and processes, it cannot be said with accuracy that the process he selects will be the best one. It might be the best one under given conditions, but it may no longer be best if conditions change. If, for example, material prices change, cheaper materials might make more expensive methods of processing more economical. In the long run, as the following chapter will explain in more detail, the total cost of processing might be less with a more expensive production process. The size of the production run, the availability of equipment, the type of labor available, and the budgetary allowance for the job will undoubtedly affect the decision on the production process. Along these lines it appears evident that a small production volume does not warrant the use of the best machine, especially if the machine could be kept busy with a more important and higher-volume job. The setup cost might be just as important as the type of labor used. A more expensive process using unskilled help might still have a lower total production cost than if skilled workers were necessary.

Which of the many production processes is superior to all others is often no more than a matter of opinion. Even if all roads lead to Rome, we must still decide which one to take. Ultimately, the decision depends primarily on cost; all other factors are subordinated to the cost factor. A case in point is the sand casting mentioned earlier. If we decide to purchase a sand casting as our raw material, it will have to go through a greater number of machining operations before it has the required shape and dimensions than if we started with a die casting. We know that each machine will have to be set up, which will be time consuming, and that special attachments will be needed, which will add to costs. Each individual operation will take a certain amount of time. When one operation is completed, the workpiece will have to go to another piece of equipment; that is, it must be transported to the next machine. The more operations and material handling involved, the greater are the chances for error and damage, to say nothing about the costs of material handling. By selecting a method which requires fewer operations, the possibility of error, rejection, and back and forth transportation is reduced and the cost of rejects minimized. Had our choice of a raw material been a die cast, the basic cost for the material would have been substantially higher, but the number of finishing operations to be performed would have been fewer in number. Once the choice of sand casting was made, the nature of the material itself precipitated the appropriate processing method. Hence, material and processing method are usually interdependent.

Processing decisions require technically trained people. Accordingly, a bill of materials is prepared to have a clear picture about the product as a whole. Subsequently, the bill of materials is analyzed item by item to determine which of the component piece parts should be purchased on the outside or subcontracted and which ones should be manufactured with company facilities. Whether a material can be purchased cheaper than it can be manufactured depends largely on the facilities available for the processing of the item or items in question. Thus, the making of a bill of materials and the writing out of process sheets must be done regardless whether the item is purchased or made.

It is hard to assess the correctness of judgment of those who determine the processing of an item. Experienced production men can often make better decisions than academically trained process engineers. The important thing is to select the cheapest process. The very nature of processing will determine to some extent the costs of production.

The production process is decided upon only after the number of operations is finalized, the sequence in which these operations must follow each other is established, the equipment to do the work is selected, the specific tools needed are determined, and last, but not least, the specific stage of development when inspection will take place is pinpointed.

Basic Facts About Production Equipment

Once the process sheet is developed, the appropriate equipment to perform each and every operation is determined. Actually, the process and the equipment are considered at the same time; that is, the process is so designed as to make use of company facilities. Occasionally equipment requires no setup, but more often the equipment must be adapted to different uses by retooling, by changing the various tool settings, or, in the chemical industry, by changing the control gage settings. However, prior to the start of production, tools usually must be acquired and attached to the machines to adapt them to specific production operations.

Although quality is important, generally speaking cost is the primary consideration in making a product a certain way. Thus, in speaking of alternative processes, we really mean that we want to make the product in the cheapest possible way. Before a final decision is made on the proper method, it is essential therefore that every possible method be analyzed.

Most of the examples used in this text in dealing with production processes and equipment will be taken from the metalworking industry because production is most difficult in that area. While chemical or other production processes may appear complicated from a chemical viewpoint, it is much easier to direct and control chemical operations than to set up plans and make processing decisions in manufacturing. In a job shop, for example, dozens of different parts are produced with limited equipment. The trick is to plan the production flow so that the various parts meet at a certain assembly station at the proper time. In the chemical industry we deal with less equipment and a limited number of products. This is also true in process industries such as steel, plastics, and glass. From the point of view of fabrication, the use of steel, plastic, or glass is immaterial, except that metal is harder and at times requires more steps in processing. For the sake of illustration, let us see what type of industrial processes exists in the metalworking trade and what is the general relationship between processes and equipment.

To determine in advance of performance the nature of processing and the sequence of machining operations with some degree of accuracy, it is essential to know the type of raw materials to be used. Generally speaking, machining, like welding, follows certain patterns. However, let us first specify what we mean by machining. Machining is that process by which semiperfectly formed and shaped metal pieces can be reduced to definite and accurate specifications and dimensions. This is done with the help of certain types of production equipment. Machining equipment does essentially the same thing as a kitchen knife; it cuts. Peeling a potato is similar to cutting the surface of a piece of metal; the difference is that only a certain type of machining job can be performed with a certain type of machine. When a potato is peeled, both knife and potato are turning and moving; in contrast, cutting tools are usually (but not necessarily) mounted on production equipment and are stationary, or at most move only in a predetermined path, while the material to be cut is clamped to a movable workbench and passed by the cutting edge of the tool. As the bench moves, the cutting tool cuts the surface of the material in the same way that a knife, if held stationary, would peel a potato moved past the cutting edge.

In certain other machining operations both the cutting tool and the bench upon which the raw material is fastened move in fixed directions. Round objects can be machined on one of several types of lathes which vary in design but not in principle. While the workpiece to be machined rotates at a constant speed, a cutting tool moves either along a diameter or parallel to the axis of the workpiece and shaves off the metal surface. Repeated cuts are made until the workpiece has been reduced to the proper dimension or tolerance. Tolerance is the permissible deviation from the dimension given on the drawing. It is usually expressed in thousandths or hundredths of an inch. It may refer to width, depth, length, or diameter.

Drilling holes, tapping, countersinking, and so on can be done on a drill press (see Fig. 6-6). In this case, the material is held stationary while the cutting tool—a drill, tap, or countersink—rotates. The drill press operator regulates the vertical feed of the cutting tool by moving a foot or hand lever. The press is equipped with stops and gages to control the depth and accuracy of cut.

Flat surfaces, or sides, can be machined with milling machines, shapers, or planers. These machine tools embody the basic machining principles: a moving tool, a moving workpiece, or both.

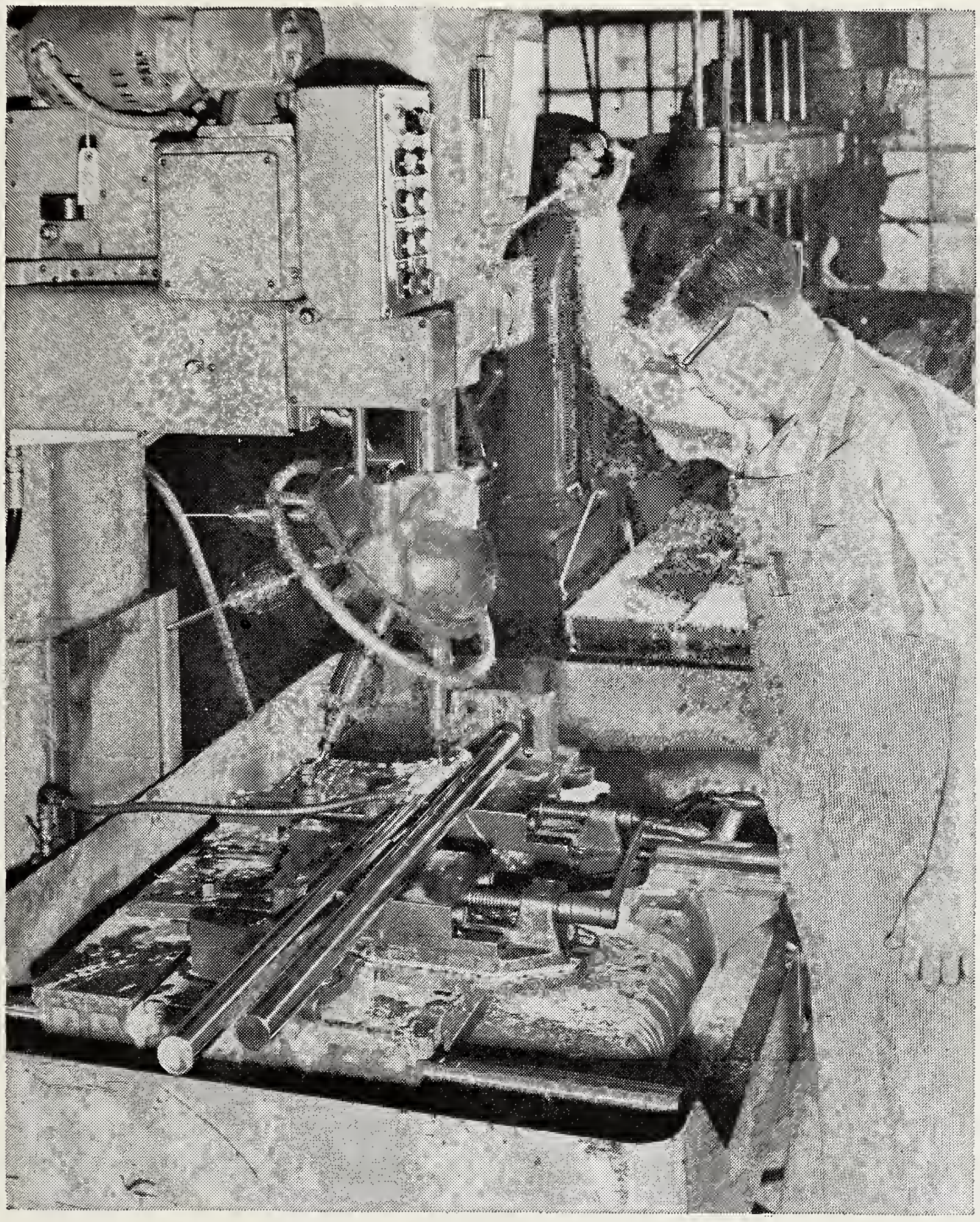


FIG. 6-6. Turret drilling machine. (Courtesy of Brown and Sharp Manufacturing Co.)

Grinders may be used either to make the surface smooth or to rough it to size. For cutting, industry uses all sorts of saws, abrasive wheels, and flames. Sometimes metal may be cut cheaper and faster with a flame, say, an oxyacetylene torch, than by any other means. Two pieces of metal may be joined by welding or by using a low-melting-point metal such as zinc. In the latter method, called soldering or brazing, the low-melting-point metal adheres to each of the metal pieces and so holds them together. Properly, the term "welding" applies to heating two pieces of the same metal until they flow together.

Metals may undergo certain treatment to prevent oxidation or to make the surface receptive to paint. This treatment may consist of a degreasing process to remove the grease used as a coolant during machining or a surface treatment process. The latter may be chemical or electrochemical. Plating, for example, is an electrolytic process which either adds beauty to a metal or builds up the size of a part. Galvanizing is similar to plating in that a coating, in this case zinc, is put on the metal. Metal spraying may be used to add to the metal or to act as a protective coat. Sand blasting, however, takes off rust and other surface dirt and leaves the metal surface smooth and clean.

Frequently, the manufacturing of parts and components requires forming and bending. For such purposes a press with mechanical or hydraulic pressure is necessary. Just as one can bend a card by placing it over the edge of a table, supporting the portion on the table, and pushing down on the part to be bent, so it is possible to bend metals into almost any shape or form. The pressure necessary will vary with the strength and thickness of the metal to be bent. There are 20-, 50-, 80-, 100-ton, and even larger presses. A special type of pressing is stamping, which is nothing but pressing or drawing sheet metal into a die mounted on a foot-, switch-, or hydraulically-operated press. Stamping can provide intricate contours, curvatures, and all sorts of shapes and deep drawings to very close tolerances (0.001 inch).

There is a vast variety of production equipment, but the examples given are enough to convey the idea of the nature of production processes. For those who earn their living by determining production processes, it is essential to know almost every detail of various equipment and processes. One should never think, incidentally, that machining applies only to metals. Most of the machining processes can be applied to other raw materials, such as rubber, plastics, ceramics, wood, and glass. The softer the material, the easier, mechanically, is the machining operation.

Before machining operations are performed, the metal may be shaped and formed to varying degrees of accuracy by melting the metal and pouring or forcing it into a mold. Some casting techniques can yield such accurate shapes and dimensions that the need for subsequent machining is negligible. The narrower the tolerances, however, the higher is the cost of the casting.

Costs tend to rise in proportion to the difficulty and degree of complexity of the molding process. Basically, there are only a few important molding techniques that concern the process engineer. The products based on each technique have their particular usefulness. A sand casting requires that a cavity be made in sand by molding the sand around a pattern which is then removed from the mold. The fluid metal is then poured into the sand mold. When the metal cools, it assumes the shape of the mold and therefore of the pattern. The reproduction is not very accurate, since there are several possible sources of error; and a great many machining operations may be needed to achieve the proper size and dimension. A machine shop uses castings or forgings as raw material; foundries and forge shops consider them as finished products.

Since in metalworking plants castings and forgings are the usual raw materials, it is not out of place here to make a further study of their properties. It stands to reason that the less accurate the casting or forging, the more machining operations must be performed on it in the subsequent stages of production. An engine block is a typical example of a casting. Since an engine block houses various parts and of itself has no functional value, the accuracy of the block is immaterial except at the points where the block mates with other parts. At such places the castings will undergo several machining operations such as rough milling and finish milling. If overall accuracy is needed, ordinary sand casting is not adequate. A permament-mold casting produces a better, more accurate raw material for metalworking plants. Essentially this is also a sand casting, but at points of sharp curving a metallic mixture ensures greater accuracy than in the sanded sections. Therefore, greater precision is achieved when molten metal is poured into the mold and cooled off.

A highly accurate image of the mold can be achieved with die casting (see Fig. 6-7). Here the mold is made of metal that is formed and shaped to high precision by skilled die sinkers. The molten casting metal is forced into the die under high pressure to fill in all the contours. Die casting at present lends itself only to raw materials which melt at low temperatures. The achievable dimensional tolerances are so tight that very little finishing is necessary. The cost of making and using die casts as raw material is, however, correspondingly high.

Instead of using air compression, some types of die casts may be made by use of centrifugal force. As the metal is poured, high-speed revolution of the mold assures that the metal fills all portions of the die cavity. This is known as centrifugal casting. Although these castings may have different shapes and forms, they are usually round items such as wheels.

An accuracy equal to that of die casting is achievable with investment casting, in which a wax replica is made of the object, usually on the basis of a preproduction sample, just as a dentist may make a wax model of a denture to be constructed by a dental laboratory. A characteristic of investment casting is that the replica is destroyed.

If we need a casting which is also strong, we need a forging. The axle of an automobile or of a railroad car must be not only properly shaped but also compressed to make it strong. Forgings are usually derivatives of castings.

The red-hot metal is hammered or pressed into a mold by using mechanical or hydraulic pressure.

The foregoing processes are described here to illustrate the inseparable relationship of process, equipment, and the material used. It should be apparent that the machining process depends on the nature of the material with which we work. If we use sand castings, for instance, the number of operations on the material will be large because of the inaccuracy of the raw material. The number of operations needed will diminish with the greater accuracy of the casting used. If we use a forging instead of a casting, the number of operations increases because the former is a much harder metal to machine. Hence, a great deal of work goes into the production of a part before it reaches the assembly floor.

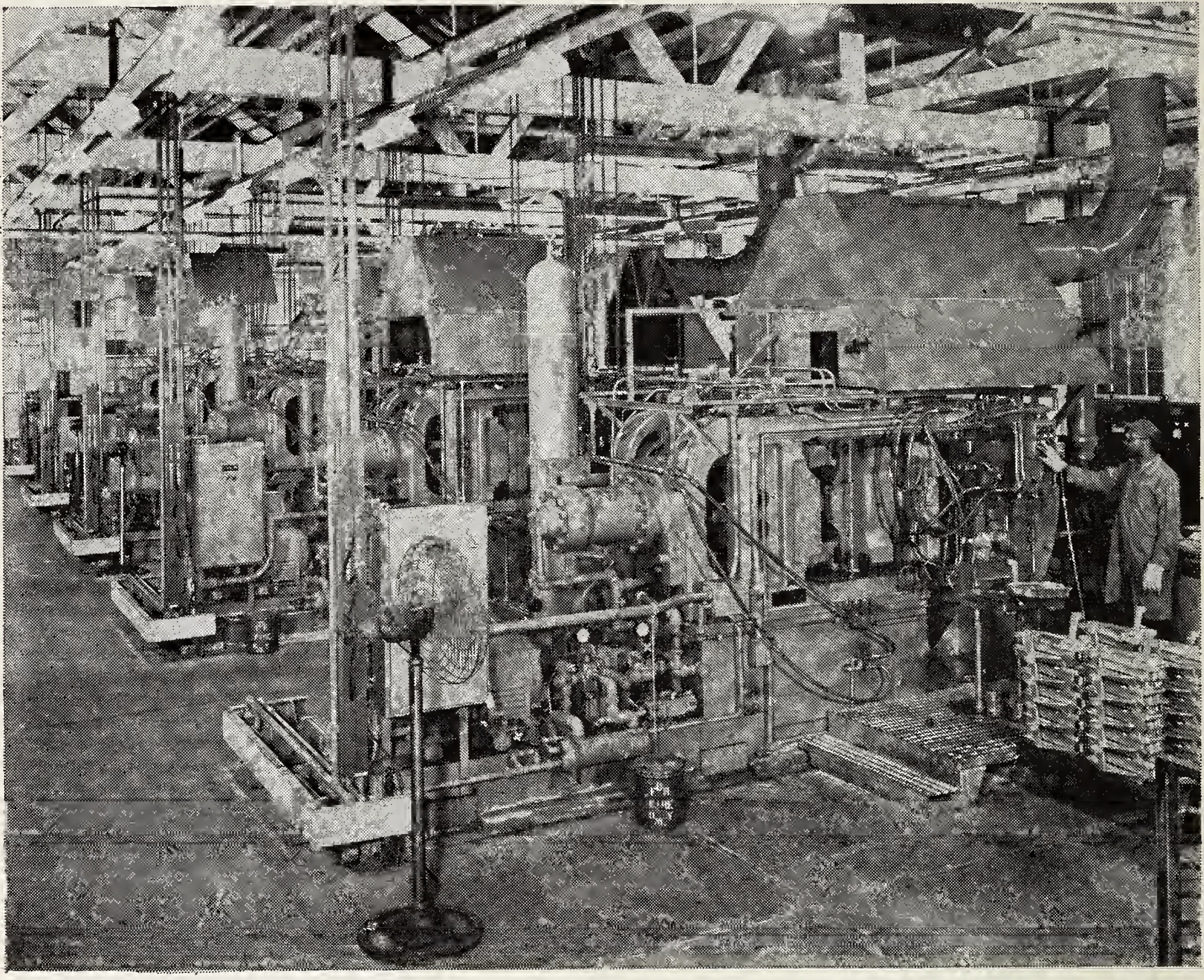


FIG. 6-7. Die-casting equipment. (Courtesy of The Singer Manufacturing Co.)

Many raw materials are processed similarly. For example, rubber, plastic, glass, ceramic, aluminum, and copper can all be cast by similar molding techniques. Assembly processes also have similarities. For example, two metal parts may be riveted or welded together or pieces of cloth may be stitched together, but the nature of the assembly remains the same.

INSPECTION

Process planning deals not only with operations involving man and machine, but also with inspection. Inspection is an important phase of the production process. Thus, if the place of inspection is not in proper sequence, production may suffer in quality and in quantity.

The process engineer should decide on the place for inspection stations as well as on the specific moment for inspection in the sequence of operations; actually, inspection is an "operation," and it must therefore be integrated into the production process. The discovery of faulty products and the prevention of further work on them can contribute to reduction of both labor and overhead cost and, consequently, help raise the efficiency of production.

It is not easy to decide where an inspection should be made. Process planners should arrive at the minimum number of inspections with the maximum assurance that defective workpieces are weeded out systematically. It is clearly wasteful to process a damaged or defective workpiece, but where and how is it to be intercepted? As a rule, the workpieces in a production process advance step by step. In between, they may be stored temporarily until the next machine becomes free to complete the next operation. Should the point of storage become an inspection station? This is a good idea only if the defective workpieces can be recognized at this stage. It is always important that possibly defective workpieces should be caught before more damage can be done, and it is especially important to catch those items which are so badly defective that they cannot be put right.

The main question, then, is always where an inspection operation should be placed in the work sequence. It should be located at that particular production stage where the most damage can be prevented. Usually it is advisable to inspect the workpiece before a long and expensive operation takes place so that, if a product is of inferior quality, time and money are not wasted. Certain operations can cause more damage than others, and the process engineer must always know which operations these are. Damage may arise because the machine has not been sufficiently well perfected to handle the job without occasional error. Frequent inspection is advisable after such a work station.

Inspection takes time and money. Inspectors do not add value to the product; they just check whether the work in process is good or bad. Therefore management tries to keep the frequency of inspection as low as possible. The inspector may check every single workpiece or check only a few samples. Whichever method is used, it is essential that the inspection uncover defective workpieces and that it be known where the error was made. The error may be mechanical or human. If the error was made by a careless employee, the supervisor knows that the worker must be watched in the future; and in this way the foreman gains information about the skill and reliability of production workers. If the damage is caused by a mechanical failure, it is essential that management know where the damage was done so that corrective action can be taken.

Control over quality may take different forms. The most common one is inspection and the less conventional one is "statistical quality control," the former is a nonpreventive and the latter a preventive type of inspection. Inspection merely tells management after operations are performed whether the workpiece is good. But if all the sources of error are known and if a continuing check is made for variation in small lots, inspection of workpieces can tell management not only when damage is being done but where it is being done. Steps can then be taken to bring quality back into an acceptable range. In the meantime, *all* of the workpieces are accepted, and the customer is promised nothing more than that rejects will not exceed a certain percentage of the total number of pieces. This, in highly simplified expression, is the basis of statistical quality control. As an illustration, the function of statistical quality control in the continuous production of screws is to state the percentage of the "probable" defective screws in a shipment. Because of the low price of the item, it would not pay to separate bad workpieces from good by inspection. So the probable percentage of error is given and the customer thus knows that he is buying not only perfect screws but also a certain percentage of imperfect ones. The reader is referred to Appendix B for a more complete discussion of statistical quality control methods.

In this section we are merely trying to show that control over quality (that is, inspection, sample inspection, statistical quality control) must be treated as if it were a productive step and given a specific "operation number," following or preceding given steps in the sequence of operations. Whether inspection is statistical, sampling, or 100% is *relatively* insignificant. Inspection at the right time and place indicates good judgment and competent process engineering.

Basic Facts About Inspection

In order to measure quality, standards of quality must be established and a simple routine by which it is easy to measure good and bad quality must be developed. Quality might refer to interchangeability or size and dimension. In the case of chemical plants, quality would refer to a certain functional utility. A shirt producer might measure quality by strength of seam, attractive appearance, and fit. In the case of steel, quality might mean a certain metal property which must be achieved in the production departments. At any rate, the quality requirement is usually indicated on the design drawing or the product specification. It becomes the function of the production people to see that the necessary quality is attained.

The inspection station has only one function: to check whether quality is being achieved and hand over the information or the imperfect products to the foremen. Quality can be measured by various visual or mechanical methods or by chemical analysis of samples. Whenever possible, measurement of quality should be made independent of human judgment. If this is done, the first step forward uniform application of quality standards has been taken.

The process engineer's function as far as inspection is concerned is to specify where inspection should take place and what its nature should be. The nature of inspection refers to the problem of sampling versus 100% inspection. Obviously, where a sampling inspection is sufficient, it should be chosen. Where 100% inspection is necessary, it is essential to determine the nature and form of the inspection.

BASIC FACTS ABOUT STATISTICAL QUALITY CONTROL[1]

Statistical quality control is in reality a formalized sampling inspection based on statistical techniques, on the laws of large numbers, and on the theory of probability. It involves a considerable amount of record keeping and charting. Statistical quality control can be considered valid and reliable only if large volumes of identical items are involved. It follows that statistical quality control methods are suitable to continuous production of standard items, and it is unusual for an intermittent job shop to apply this technique of inspection.

In the intermittent job shop, the closest we come to a statistical quality control is when we resort to sampling inspection based on random selection of the workpieces. In certain job shops, sampling is all that can be done, because a 100% inspection would destroy all the products if the necessary tests were made by consuming or exploding the product.

PROCESS DESIGN AND RE-LAYOUT

To ensure that production can be started under the most favorable conditions, it is advisable to make a periodic review of the layout of plant facilities. The process sheets available from previous production jobs and from present work may show changes which the company would be well advised to make. Business is dynamic, and growth compels change.

We said earlier that the typical intermittent job shop layout follows the functional principle. This means that its departments are arranged in a logical order although the layout caters to the production of no particular item. We might ask what we mean by a logical order when we lump equipment of similar functional utility in the same section of the plant without any regard to the process sheet. Although in job shops none of the orders is usually large enough to warrant a special layout and the sequence of operations is seldom the same for two jobs unless they are repeat orders, it is customary to suit the layout to the majority of jobs. Over a period of time, however, production sequences may undergo certain changes, since most companies tend to become specialized in certain types of work. Upon careful analysis, it can be observed that over a period of time the preponderance of the work follows a given common path. Further study may reveal that certain frequently occurring operations account for more than their proportionate share of the production cost and time.

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[1] See Appendix B.

A classification of operations and a tallying of performance times of similar or identical operations may indicate the most suitable and costwise-best arrangement of production facilities. The data furnished by such an analysis of process sheets will make possible a re-layout of departments favoring those departments in which the preponderance of operations occurs. The plant layout engineer's aim is to create a flow plan of common operations that allows an effective grouping of production equipment resulting in low-cost operations and minimum handling of materials in the production process. Such a departmental arrangement will ensure that backtracking will be kept at a minimum.

Figure 6-8 illustrates the possibilities for arrangement of production departments. If the study shows that the departmental arrangement A–B–C–D is the feasible one, the plan should be as in diagram 1; if, however, the preponderance of production operations follows the D–F–A–B–C sequence, then the departmental arangement should be as in diagram 2.

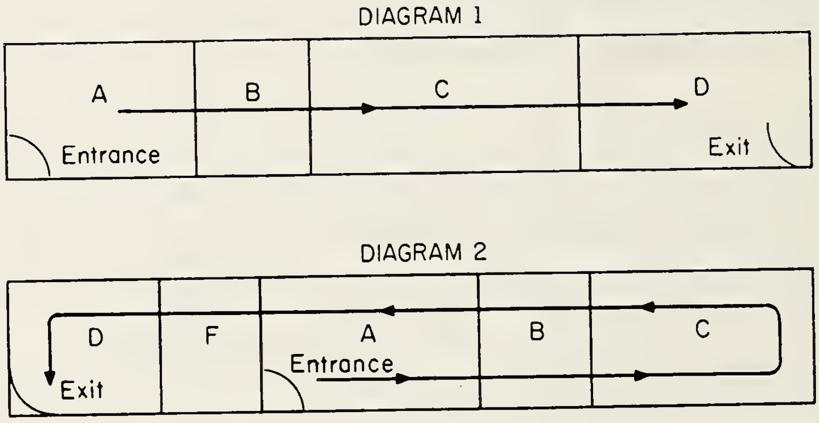

Fig. 6-8

Arrangement of the production flow in diagram 1 indicates that the raw material arrives in the receiving department, then usually goes to the department shown as B, then to the department shown as C, and finally leaves from the shipping department, D. The arrangement in diagram 2 shows that the product takes a U-shaped flow or that some of the products go from department A toward F and D or in any number of combinations but that the center of production is department A.

A properly laid out intermittent job shop provides an easy production flow for most of the products worked on, the smallest amount of backtracking, the least amount of material handling and transportation, and, in general, facilitation of the production of most of the items. Of course, the arrangement might take other forms or shapes than the two indicated in Fig. 6-5.

Yale & Towne Manufacturing Co.[2] rearranged the layout of its Philadelphia plant to assure low-cost production. This typical intermittent producer considered the success of its operation to be due to good layout and effective materials handling. Savings in the distance that the material moves range from 30 to 50%. The layout was designed to fulfill eight basic requirements:

1. Adequate facilities to receive, inspect, and distribute maximum influx of material
2. Short routes to principal store areas containing facilities to store maximum anticipated quantities of material and short, direct routes for movement of material to initial and subsequent operations
3. Proper arrangement of machinery and equipment in each department to provide ample room for placing material within easy reach of workers
4. Free access to machines and assembly benches for quick delivery of material within each department and for fast pickup of outbound material and waste
5. Grouping of machines and departments so that the movement of material between operations is as short as possible, with a minimum of backtracking and needless hauling
6. Adequate storage facilities for material in process between operations
7. Stockrooms and tool cages with facilities to receive, store, inventory, and disperse parts and tools with minimum handling and effort
8. Facilities to pack or crate finished products efficiently and to ship by all classes of carriers

Figure 6-9 is a reproduction of a typical process sheet that indicates each step which must be taken on the product. The student should note the technical information given. Although this process sheet can be changed by methods engineering, as a rule the method suggested by the process engineering department is not changed. It is turned over to the time study and production control departments.

Methods and motion study engineers frequently study the process sheet to discover whether improvements can be made on the process. However, in intermittent job shops it seldom pays to go over the process sheet and subject it to a detailed analysis. Methods and motion study engineering is more common in continuous production. There the production process must be almost perfect, and a considerable amount of time and effort is spent on improving it. For the purpose of process analysis, process sheets are made, and by using the symbols shown in Fig. 7-2, it is determined whether a cheaper method of performing the various operations is available.

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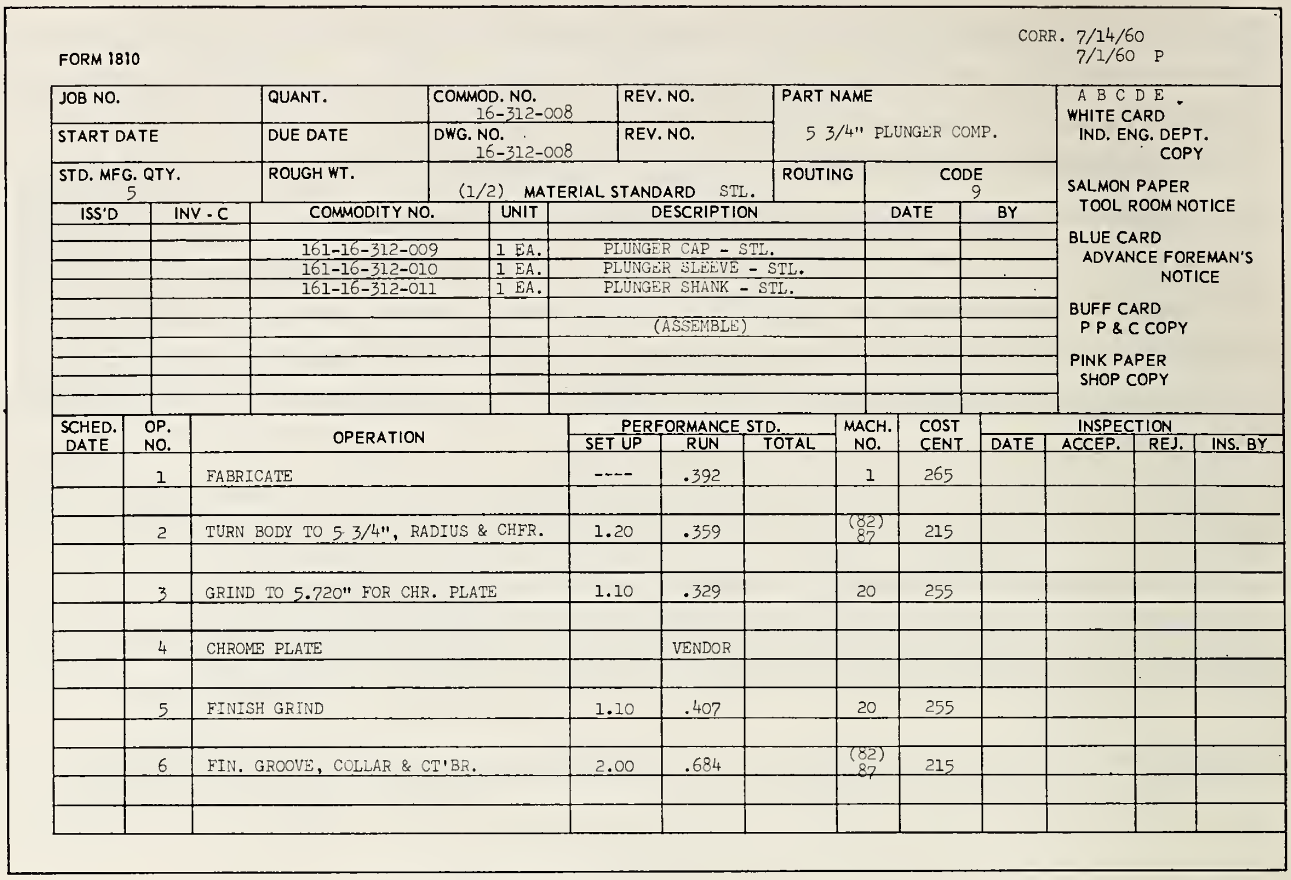
[2] *American Machinist*, Dec. 30, 1948, p. 33.



FORM 1810

CORR. 7/14/60
7/1/60 P

JOB NO.	QUANT.	COMMOD. NO. 16-312-008	REV. NO.	PART NAME 5 3/4" PLUNGER COMP.	A B C D E WHITE CARD IND. ENG. DEPT. COPY
START DATE	DUE DATE	DWG. NO. 16-312-008	REV. NO.		SALMON PAPER TOOL ROOM NOTICE
STD. MFG. QTY. 5	ROUGH WT.	(1/2) MATERIAL STANDARD STL.		ROUTING	CODE 9

ISS'D	INV - C	COMMODITY NO.	UNIT	DESCRIPTION	DATE	BY
		161-16-312-009	1 EA.	PLUNGER CAP - STL.		
		161-16-312-010	1 EA.	PLUNGER SLEEVE - STL.		
		161-16-312-011	1 EA.	PLUNGER SHANK - STL.		
				(ASSEMBLE)		

BLUE CARD
ADVANCE FOREMAN'S NOTICE

BUFF CARD
P P & C COPY

PINK PAPER
SHOP COPY

SCHED. DATE	OP. NO.	OPERATION	PERFORMANCE STD.			MACH. NO.	COST CENT	INSPECTION			
			SET UP	RUN	TOTAL			DATE	ACCEP.	REJ.	INS. BY
	1	FABRICATE	----	.392		1	265				
	2	TURN BODY TO 5 3/4", RADIUS & CHFR.	1.20	.359		(82) 87	215				
	3	GRIND TO 5.720" FOR CHR. PLATE	1.10	.329		20	255				
	4	CHROME PLATE		VENDOR							
	5	FINISH GRIND	1.10	.407		20	255				
	6	FIN. GROOVE, COLLAR & CT'BR.	2.00	.684		(82) 87	215				

FIG. 6-9. Typical process sheet.

TOOLS AND PROCESSES

The fact that the process is individually designed for each part and that the plant layout is logically arranged to suit the majority of orders means that production preparations are not completed until the jigs and fixtures are designed. The machines cannot perform work, as already explained, unless the appropriate jigs and fixtures are mounted on them. Fixtures hold the workpieces steady while the operation is performed; jigs guide the cutting tools into the proper position. A jig is a precision tool and must be designed as carefully as the product itself is designed, because faulty jigs will produce faulty products.

If one has proper jigs and fixtures (from here on called tools), the work can be performed easily and properly without placing too much reliance on the judgment and skill of workers. With the right tools it is possible to make dozens and dozens of identical workpieces. When parts must be interchangeable and one is dealing with precision parts, tool design deserves special attention. Through these tools it is possible to adapt standard production equipment to any kind of job.

Thus, when the production process is determined, the process sheet, along with other production information (drawings, quantity and quality specifications, etc.), is turned over to the tool design department. If the company is not large enough to have its own design staff, it usually turns to a tool firm which designs and makes the tools for the company. In many shops, making the tools is part of the contract. This means that process planning extends not only over the product but also over the tools. In this case, the company's own skilled mechanics produce the tools for the various production jobs handled by the company. Frequently, the foremen and superintendent can, and do, design suitable jigs and fixtures. The tools are sent directly to the production site or to a central toolroom, depending on the size of the company. Toolrooms store the jigs and fixtures until needed. At times, the tools are remodeled and used on other, similar jobs.

In summary, the proper choice of operation and equipment, attachments (jigs, gages, dies, and fixtures), and operation sequences will bring about a relatively smooth flow of production from department to department and keep the cost of production at a minimum. Tools adapt the equipment to a multiplicity of uses as well as enable the employment of unskilled help in place of skilled craftsmen. From the point of view of production costs, this is of considerable importance.

SUMMARY

PLANNING FOR INTERMITTENT PRODUCTION

The intermittent producer accepts small orders to be made to the customer's specification. In view of the individuality of the orders, he has to cope with new technical problems every time a new order comes in. Even though the problems may be similar to others faced in the past, they are really new problems which require new plans on the part of the engineering planning group. Process design must be made in light of existing plant layout and other considerations related to equipment. Needed time and motion studies must be made as new jobs arrive.

PROCESSING CONSIDERATIONS

In the production cycle, process engineering is a prerequisite to most planning activities. The function of process engineering is to determine the best processing method under the prevailing plant conditions. Process engineering consists of two functions:

1. Preparation of bills of materials (parts list)
2. Preparation of process sheets

This is not an easy job because of the many and various technical and cost considerations involved.

BILL OF MATERIALS

The bill of materials is a systematic listing of parts which make up the product and is based on the blueprint. The engineer who prepares the bill of materials (frequently a draftsman can also do it), systematically takes off the drawing the various parts until he has made a list of every component of the product. Although not a good example for a job shop, sport shirts may be broken down into the components of pocket, left front, right front, buttons, yoke, sleeves, back part, collar, etc. When a bill of materials does not contain assemblies and subassemblies, we call it the parts list. The parts list is used to determine which parts are to be made and which are to be purchased from outside vendors. It is possible that, before that decision is made, a process sheet may be developed for the sole purpose of determining the sequence of operations and the inherent costs.

The company usually produces the item if it can be made in the plant cheaper than the vendor can supply it. At times a plant may decide on production even though that cost is higher than the vendor's price. As long as a company can break even in the long run, it may be advisable to produce the item in the plant so that company equipment is utilized and the company does not have to lay off workers. Before reaching such a decision it is essential to know the cost of processing, and tentative process sheets must be made for that reason.

PROCESS SHEET

The process sheet is prepared on the basis of a considerable amount of contemplation. It requires technical knowledge, production know-how, and cost consciousness. A practical man with appropriate background can successfully complete a feasible list of operations to be performed on a given item. Usually the process sheet refers to the production of parts as well as to their assembly.

The sequence of operations constitutes one of the tasks imposed on the process engineer or on whoever determines the process. In addition, the process sheet contains information about the type of equipment which must be used to perform the operation. It may also indicate the speeds and feeds with which the operation must be performed; the gages, jigs, and fixtures which must be used; and much other technical information. Eventually, quality standards are also listed, since tools and equipment have certain limitations and there is a very definite relationship between the quality which must be attained and the equipment which can attain it.

It is not unusual for the process engineer to also determine the approximate setup time. Setup refers to the activity of preparing the equipment so that it can perform a given job. General-purpose machinery—in intermittent job shops it is common practice to have multipurpose equipment—must be set up before it is able to perform certain machining operations. The tools (jigs, fixtures, gages) must be mounted on the machine before the worker can perform the operation. In some companies management maintains a separate department to furnish setup men where they are needed. In smaller companies, the employees themselves set up their machines before they start the operations. Setup time may be important as far as scheduling and wage payments are concerned.

Those who determine processes are bound to make selections from a variety of processes suitable for the particular job. The limiting factor is associated with the equipment and the quality it can attain (cutting speeds, surface finish, cost of running, etc.). Not infrequently, redesign of the item becomes necessary while processing is taking place.

Each part must have its own process sheet, which should include all steps even though equipment is not available for all of them. It is not unusual for operations, say, 1 to 5 to be performed in the plant, operations 6 and 7 by a subcontractor, and finishing operations 8 and 9 in the plant again.

A collection of process sheets for past and present orders can be analyzed and used for improvements in plant layout. Plant layout must be so adjusted that the most frequently used departments are located in a convenient section of the plant.

The process sheet, along with other technical information, is also used by the tool department, which in intermittent job shops plays an extraordinarily important role. Since intermittent shops produce nonstandard items in small quantity, it stands to reason that the equipment used by intermittent producers is useful for a variety of purposes. Thus, each operation on every part calls for special jigs and fixtures, and at times for special measuring devices. Thus, each time a new order is received, it is essential that the tools be designed and made. The production of tools is one of the main headaches of job shops. Equipment is practically useless unless the tools are available.

Process planning is a dynamic function. With the development of new cutting tools, production processes tend to become obsolete. Furthermore, with the use of new raw materials, older production processes become less practical than new ones. Thus, process engineers must constantly search for better methods and for the application of better tools. A competent process engineer is not afraid to experiment and to use new methods to reduce his costs.

That a process is determined does not mean that production will actually follow the predetermined production process. When a costly order is to be processed, it often happens that, before acceptance, the process is checked by methods engineers whose main task it is to see if they can improve on the chosen method. A good methods engineer may find better and more suitable tools to facilitate production. However, job shops as a rule do not make too much fuss about methods study because of the generally short-run nature of most of their orders.

QUESTIONS

6-1. What is engineering planning?

6-2. How does engineering planning contribute to successful production?

6-3. What is the function of the bill of materials?

6-4. What is the function of the process sheet?

6-5. How does the engineering planning group help other staff (or line) members of the management?

6-6. Does the inspection belong to the production process?

6-7. Where in the production process should the inspection station be located?

6-8. What is the relationship between process design and plant layout?

6-9. What is the relationship between plant layout, process engineering, and inspection?

6-10. What knowledge is essential to process engineering?

PROJECTS

6-1. Develop a bill of materials from an assembled item in your home, such as a kitchen table or chair. If you are keen and have the time, make up a bill of materials of a typewriter.

6-2. Develop a process sheet for a) the production of a pair of gloves made of leather, b) the assembly of a textbook, c) production of beer, d) bottling of five different soft drinks with the same bottling devices.

6-3. Write to producers engaged in steel production and ask for descriptive material in connection with the production of steel. Alternatively, write to producers either of automobiles or gasoline.

CASES

6-1. The Thomas Emerson Company

The Thomas Emerson Company is located in a suburban area of Chicago and employs nearly one hundred workers. The employees are mostly skilled machine operators, but one-third of them are unskilled or semiskilled female workers. The company is engaged in intermittent production of precision and nonprecision work to be completed according to customer's specifications. Actually, the company has accepted any kind of machine shop work provided that equipment or, more accurately, equipment time has been available. The raw materials of the company are usually forgings or castings. These are then machined according to customer's specifications. Thus, for instance, the company once received an order for a specially designed racing-car crankshaft. The forging was ordered from Kropp Forge, and after it was machined, it was shipped as a finished crankshaft to the automobile manufacturer.

At times, the company practices so-called partial production contracting. This means that it accepts an order for a given part even though company facilities are inadequate. This is in line with the policy of the company to keep men and machines busy even though it may cause some problems as far as production is concerned. Accordingly, it is the policy of the company to take orders as long as some of the operations necessary can be performed with company facilities. This is a usual situation: Order *X* was received for a few plates. It had to go through fifteen different operations before it was considered a finished part. The company could not perform operations 4 and 7 owing to lack of appropriate equipment or because its equipment was too busy with other work. Despite the fact that equipment time was not available, it was still profitable to accept the order. In such instances, the company performed all the necessary operations except those for which it did not have the equipment. Those operations were subcontracted. Despite the high cost of transport to and from the subcontractor and despite a somewhat higher operating cost, in the long run the company profited by accepting the order, because it made money on those operations which it could perform.

This method of subletting certain operations to another firm is not unique to the Thomas Emerson Company. In intermittent production most companies subcontract those operations which they cannot perform. It is unusual in many types of production for a company to have all the equipment required for that production. Most intermittent job shops work on small orders of a specialized nature, and when certain orders require a special type of equipment, the purchase of that equipment is not warranted.

Also, there are occasions when the Thomas Emerson Company accepts new jobs for which it has the necessary machine but constant rescheduling of orders owing to breakdowns or rush jobs have overloaded that equipment. To meet previously established schedules and delivery commitments, the company must obtain the necessary equipment time. To catch up on the backlog, the company frequently operates on overtime, setting up second and third shifts; but when that alternative does not yield the required production, subcontracting of surplus work is the only solution left.

At the Thomas Emerson Company, production superintendents are responsible for all price and delivery commitments even though staff groups work out the details. When the company receives an inquiry, it is forwarded to the production people who would be concerned with the job. The sales department discusses the problem with customers, but when technical details have to be worked out, the call is transferred to the appropriate executive. After preliminary discussion, further details are worked out by the cost estimating department in close cooperation with process engineering and industrial engineering, who handle standard costs as well as time and motion studies. The delivery commitment is determined by the production planning department. The system is shown in Fig. 1.

Finally, the production executive receives detailed information from those who perform the various calculations on the one hand and make up the process sheet on the other. After approving the estimates, he reports back to the sales department. In conformity with the above procedure, sales submits a price and several feasible delivery possibilities, indicating two or more alternative delivery dates to customers.

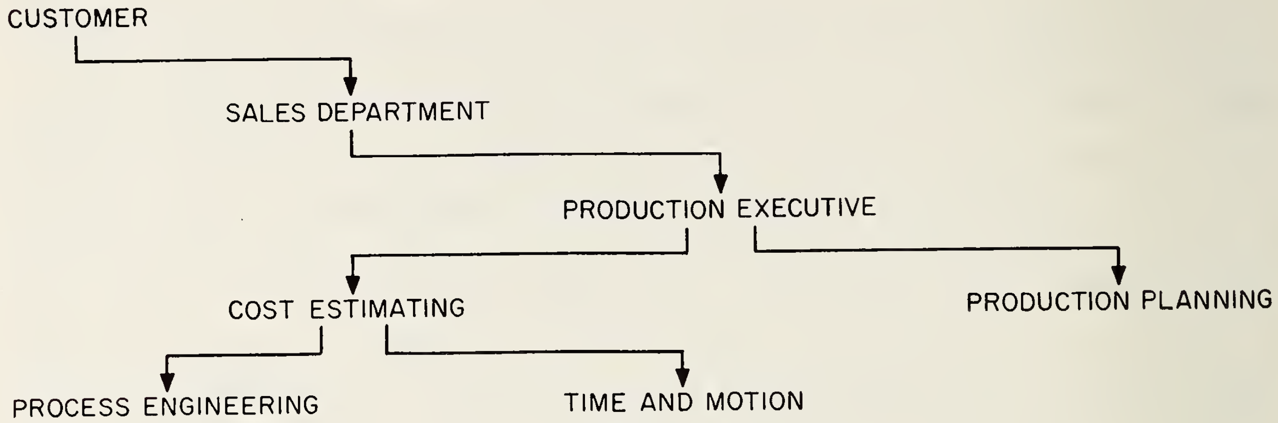


FIG. 1

The company has several departments. They are laid out functionally rather than according to the line principle and are as follows: a milling department with three milling machines, a drilling department, a grinding department, a weld shop, a paint shop, and a number of other smaller departments with some large equipment including a sandblasting machine, press brake, 150-ton press, 80-ton press, and 40-ton press. There is also a utility department with other standard machine shop equipment: shapers, lathes, grinders, saws, buffers, honing machines, etc.

Ordinarily the orders received by the company are small. At one time, however, the company had a chance to pick up subcontract work from a large electronics manufacturer. The job was an aluminum housing, a casting which had to be machined to specifications and delivered periodically at the rate of 800 to 1000 pieces per month. Since the company usually received small orders, it was seldom necessary to make a big fuss about process design or time studies. As a rule it did not pay to spend a long time on process engineering, tool design, or time studies. Usually only a quick study was made, yet the company's production and industrial engineering departments operated quite satisfactorily. But in view of the size of the prospective order—20,000 units plus 1% extra to compensate for the expected rejects—the production superintendent in charge of the machine shop asked that the cost estimating department make its calculations with extreme care. Any slip in cost estimating could be disastrous.

First of all, the cost estimating department had to collect information about raw material prices. Foundries had to be contacted through the purchasing department to find out the best price on aluminum castings. The process engineering department had to prepare a process sheet, and subsequently the time study people had to estimate operation times. The time study problem was not a serious one, since the company had accumulated time study data from other, similar jobs and the times taken to drill holes, mill surfaces, bore large-sized holes, and so on do not vary substantially from job to job. Although there were differences between drilling holes in steel, brass, aluminum, etc., time discrepancy could easily be calculated. Once operation sequences were determined and tooling-up as well as operation costs

Sequence of Operations		Base Time	Base Time + Allowances		Output per Hour Required		Actual Output
No.	Name	Decimal Minutes	First	Second	Min.	Max.	
1	Inspect. of cast.	1.50	1.67	2.00	30	35	15
2	Drill 11 holes RD*	3.70	4.13	4.95	12	14	5
3	Mill top face	1.73	1.93	2.32	25	31	11
4	Mill feet	0.44	0.49	0.59	101	121	51
5	Mill left side	0.95	1.06	1.27	47	56	25
6	Mill right side	0.95	1.06	1.27	47	56	24
7	Mill back	0.50	0.56	0.67	89	107	42
8	Mill face f.p.l.	0.43	0.49	0.59	101	121	55
9	Mill face f.r.s.	1.25	1.39	1.67	35	43	20
10	Rough mill keyway	1.35	1.51	1.81	33	39	19
11	Finish mill keyway	1.28	1.43	1.71	35	42	21
12	Mill cam face	0.28	0.91	1.10	54	65	28
13	Bore hole f.26p. RD	2.10	2.34	2.87	21	25	12
14	Drill rem. pile. 3/8s	3.25	3.62	4.35	13	16	6
15	Drill feet }	2.50	2.79	3.35	17	21	9
16	Tap feet }						
17	Drill 20 holes	4.12	4.59	5.51	10	13	4
18	Counterbore 20 holes	1.50	1.67	2.00	30	35	16
19	Tap	0.50	0.56	0.67	90	108	41
20	Drill L-16 holes	3.57	3.98	4.78	12	15	5
21	Tap L-16 holes	1.57	1.75	2.10	28	34	13
22	Drill U-3 holes }	0.80	0.89	1.07	56	67	27
23	Tap U-3 holes }						
24	Drill M-4 holes	0.32	0.35	0.43	140	168	79
25	Tap M-4 holes	0.42	0.35	0.43	140	168	80
26	Fin. mill top face	2.00	2.23	2.68	22	27	12
27	Inspection	↑		↑			
		time requirement if uninterrupted performance would take place		time to calculate production flow under job shop conditions			

* RD=radial drill.

Although the time study data were pretty close to the synthetic (elemental data) time standards established during the preliminary calculation, costs which were accumulated during the trial run did not match cost figures on the basis of which estimates were figured.

were calculated, the company could present the customer a bid price at which it could accept the order.

Process engineering in the preliminary study (which was revised later; see the table on page 235) decided that operation 1 should be an inspection of the rough casting. Operation 2 would be a complicated drilling operation during which eleven holes would be drilled on the side of the casting. The most suitable equipment for the operation appeared to be the big radial drill. Operations 3 to 7 were milling operations requiring the milling of the top face of the casting, then its feet, left side, right side, and back side. These operations could be performed either with the horizontal or the vertical milling machines, depending on availability of equipment and, of course, on the type of jig and fixtures to be designed for this purpose. Operation 8 (mill face for pilot light) had to be done on the horizontal mill by the very nature of the operation. While rough-mill keyway (operation 9) and finish-mill keyway (operation 10) had to follow each other, the sequence of operations 3 to 7 was a toss-up. A milling machine was to be used to perform operation 11 (mill the cam face). Operation 12 (bore a hole for a pin connector) required a radial drill. (Note that operation 12 finally became operation 13.) Operation 13 was again a milling operation (for a remote switch); operation 14 required a drill press (⅜-inch shaft for a remote pilot). Operation 15 was designated to drill and tap feet, for which a floating-table two-spindle drill press was suitable. Operation 16 was to drill twenty small holes (drill press). Operation 17 was also a drill press job (5⁄16-inch hole drilled and tapped) for which a two-spindle drill press appeared suitable. It was debated at this point whether or not drilling should be followed by tapping or whether tap-locks should be inserted into the workpiece. Since tolerance requirements were so close, it was questionable that drilling and tapping operations could be run by semiskilled female workers. Operation 18 (counterbore) was also a drill press job and could be done on a one-spindle drill press. Operation 19 was a tapping operation (drill press with tapping head). Operation 20 was assigned to an automatic drill press, and operation 21 to a two-spindle drill press (drill and tap). Operation 22 required another two-spindle drill (three holes to be drilled and tapped). Operation 23 was to drill four holes and tap the holes thereafter. Operation 24 was a drilling operation, and 25 was an inspection operation, including deburring. The last operation, 26, was a finish milling of top face. To have an airtight fit, the top of the milling surface had to be completely smooth. Therefore, tolerance was very tight. After a careful study of the sequence of operations, certain operations were interchanged. Finally, the production process listed on the time study data sheet (see the table) was accepted. Thus, the preceding description represents merely contemplation, not the actual processing method.

The cost estimates (based on elemental times, a synthetic time study techinque) indicated that the company might be able to offer a price low enough to get the order. The bid was approved by the shop superintendent. Thereupon the sales department prepared a formal bid and agreed on staggered delivery of 800 to 1000 pieces per month depending on the electronics manufacturer's release schedule.

The company got the job, and the contract was assigned order number EL-2225. Even before the Thomas Emerson Company got into full-scale production, the primary contractor intimated that there was a good chance of a repeat order. It was not certain who would get the next overall contract—it was a government-announced one—but it was likely that the same primary contractor would get it. EL-2225 was a subcontract from that producer. And even if the government were to award the second contract to another company, the chances were that the subcontract work would go to the Thomas Emerson Company because the tool-up job was already done and the Thomas Emerson Company had a competitive advantage. In other words, it was not likely that any other company could make the housings cheaper than the Thomas Emerson Company, since the latter could calculate its costs without charging for tool-up. In relatively large scale production, the costs of tool-up might be quite substantial.

In view of the unusually large production volume, a rearrangement of equipment was contemplated; but although re-layout was advisable, arguments were voiced against it. Industrial engineers were of the opinion that the job would last long enough to warrant an adjustment of layout. Company production experts stated, however, that the same equipment would be used for many different jobs even during the EL-2225 contract; the existing arrangement of equipment should not be disturbed just because of the housing job. The advisability of plant layout changes was discussed steadily, but decision was not reached until the first 100 units of EL-2225 were completed. These were produced on a pilot-run basis.

It became apparent that the original layout was inadequate to handle such a large production volume effectively. In the past, production runs had been short (as low as three to four pieces, but rarely over a hundred), whereas now they were in terms of 800 to 1000 pieces per month during a period of 20 months at least. If the new contract were also awarded to the Thomas Emerson Company, it might make it a 40-month job.

Monthly working days were 20 to 23 days, and it was estimated that the EL-2225 would tie down company equipment for at least 10 days every month. Therefore, the milling and drilling machines and the rest of the equipment could still be used in the production of other items for 10 to 13 days out of the month.

The bulky nature of the castings (they were about the size of a beer carton) was a complicating factor as far as the continuous flow of production was concerned. It was impractical to run more than 100 pieces at once on the existing plant layout. This was not the most economical production lot quantity, but the space available did not permit maneuvering more than four pallets around the machines involved. Each pallet held up to 25 castings, and even these were in the way, because pallets blocked aisles and hindered movement and materials handling in general. This meant that setup times might be excessive and employees might be spending a great deal of their time on unnecessary handling of materials.

After the trial run of the first lot of 100 pieces, the time study data—based on actual time study using the stopwatch and the snap-back method—indicated results given in the table. Based on present unit cost it appeared that the company would lose money unless time standards could be enforced. The production superintendent wanted to know why total production time per housing was two to three times higher than it should have been. Apparently, the synthetically determined time study data were correct, because they consistently fell between the two allowance factors. According to company policy, 11½% allowance was given for the necessary human needs (rest room, washing of hands, unforeseen delays, etc.) and an additional 20% for delays caused by materials handling and setup time. As a rule, the standards were considered satisfactory. At this time, however, actual output was far below the required output quota. The output quota was divided into minimum and maximum requirements. If production of employees was above the minimum, management knew that workers were performing satisfactorily.

Obviously, the cost data were based on synthetic time study procedures; yet direct time studies made during the trial run indicated that production should be much higher than employees' time cards indicated. Employees working on order EL-2225 punched their time cards when they started on the job. They punched out when the job was finished. Supervision was very strict during the trial period. Foremen were there to see that everything went according to plan. But at the end of the pilot run, the sad situation was discovered that costs were considerably higher than originally estimated. Indeed, costs were so high that the company could produce these units only at a loss. Something had to be done to improve the production flow, to reduce excessive handling, and to reduce setup time as much as possible. This conclusion was reached after executives studied the time study data. Although employees performed the operations within the time allotted for the operation, they lost a great deal of time afterward. To begin with, it was difficult to have a continuous flow of operations because operation times were not synchronized with one another. Everybody realized that it was a pilot run, but nobody could understand why there was such a great discrepancy between actual output and required output. It was therefore decided that before full-scale production could start, considerable time should be devoted to surveying the production sequences, the methods, the tool design, and the plant layout. The fact remained that the order was large enough to warrant a re-layout of facilities. The importance of this job during the next 20 months, and possibly during the next 40 months, would justify the expenditure. The acquisition of drill presses, at a cost of $140 to $160 each, was even suggested because the presses would permit a line layout of drilling operations. It had to be decided how the three milling machines and the radial drill could keep up with the drilling line (a production line as far as the drilling operations were concerned).

A few weeks later, those who were immediately concerned with the solution of the problem had another shock, one which precipitated action. The aluminum company which was to furnish the castings went bankrupt, and there was not a single foundry which could supply the company with castings at $5 apiece. The best offer was $11.50. In other words, the bankruptcy raised company costs by $6.50 per casting. However, the foundry returned the molds, which were Emerson's property.

Original cost estimates were as follows:

Materials cost	$ 5.00	
Labor cost	2.40	(approx. 60 minutes × $2.50 per labor hour)
Overhead cost	4.80	(200% of estimated labor rate)
	$12.20	
	1.20	(profit, 10%)
	$13.40	(contract awarded on basis of this unit price)

The impossibility of purchasing castings at $5 apiece was due to recent wage raises in the aluminum industry and the fact that new government demand for fighter planes had increased the demand for aluminum. Furthermore, the Detroit foundry had apparently made an error in its bid and the Thomas Emerson Company could consider itself lucky if the foundry shipped all the prepaid castings. (The company had agreed on advance payment for the castings; the Thomas Emerson Company paid for the first 110 units, and the next shipment was due in 30 days after the 110 samples were accepted.) Unless the company could find a cheaper source of supply, the cost structure looked like this:

	Original Estimate	New Estimate
Materials cost	$ 5.00	$11.50
Labor cost	2.40	6.00
Overhead cost	4.80	12.00
	$12.20	$29.50
Profit	1.20	0
Total	$13.40	$29.50

Thus, there was a potential loss of $16.10 per unit. The seriousness of the situation prompted quick action, and the engineering planning staff went to work to eliminate all the inefficiencies. There were reasons for worry, such as scheduling and being able to meet delivery commitments. At this point a question arose as to whether the company should bid for the new repeat job and, if so, at what price.

At a hurriedly organized luncheon meeting the following action was outlined:

1. Processing methods must be analyzed.
2. Each individual operation must be studied to see if better tools and fixtures could save time as far as operations were concerned.
3. Operations must be synchronized with one another to provide a better flow of production.
4. The existing plant layout, as far as EL-2225 was concerned, must be analyzed.
5. The lot size (110 pieces constituted a tentative lot) must be reconsidered.
6. If all the above were considered and successfully resolved, the company wanted to simplify operations to such a degree that semiskilled workers could replace employees who were averaging $2.50.
7. Investigate whether acquisition of additional drill presses was warranted.
8. Determine a method whereby employee output could be quickly as well as easily measured and which guaranteed employee performance.
9. Establish supervisory techniques to keep track of setups and changeovers efficiently.
10. Determine whether materials handling or temporary storage could solve the acute space problem satisfactorily.

The next day, in conformity with the above outline, the industrial engineer in charge of the project presented the diagram shown in Fig. 2. The arrow indicates the general flow of the operations. Raw material is transported from receiving to the temporary storage area and from there to the inspection area. The pallet with 25 castings is deposited (movement 2) in front of the radial drill on which operation 1 is performed; from there the pallet is transported (movement 3) to the other side where milling machines from left to right perform the first few milling operations. In between the two horizontal millers stands the vertical miller. Operations move from left to right. After the last milling operation is performed, work goes successively to the radial drill for a second time, to a floating-table drill press, to a one-spindle press, and to a two-spindle drill press. As shown in the floor layout, the various drilling and tapping operations are divided among the drill presses. Finally, the pallet is transported from the drilling department back to the inspection department. Inspection is performed where convenient and is spread all over the plant. Then the work goes back to the milling department as at first.

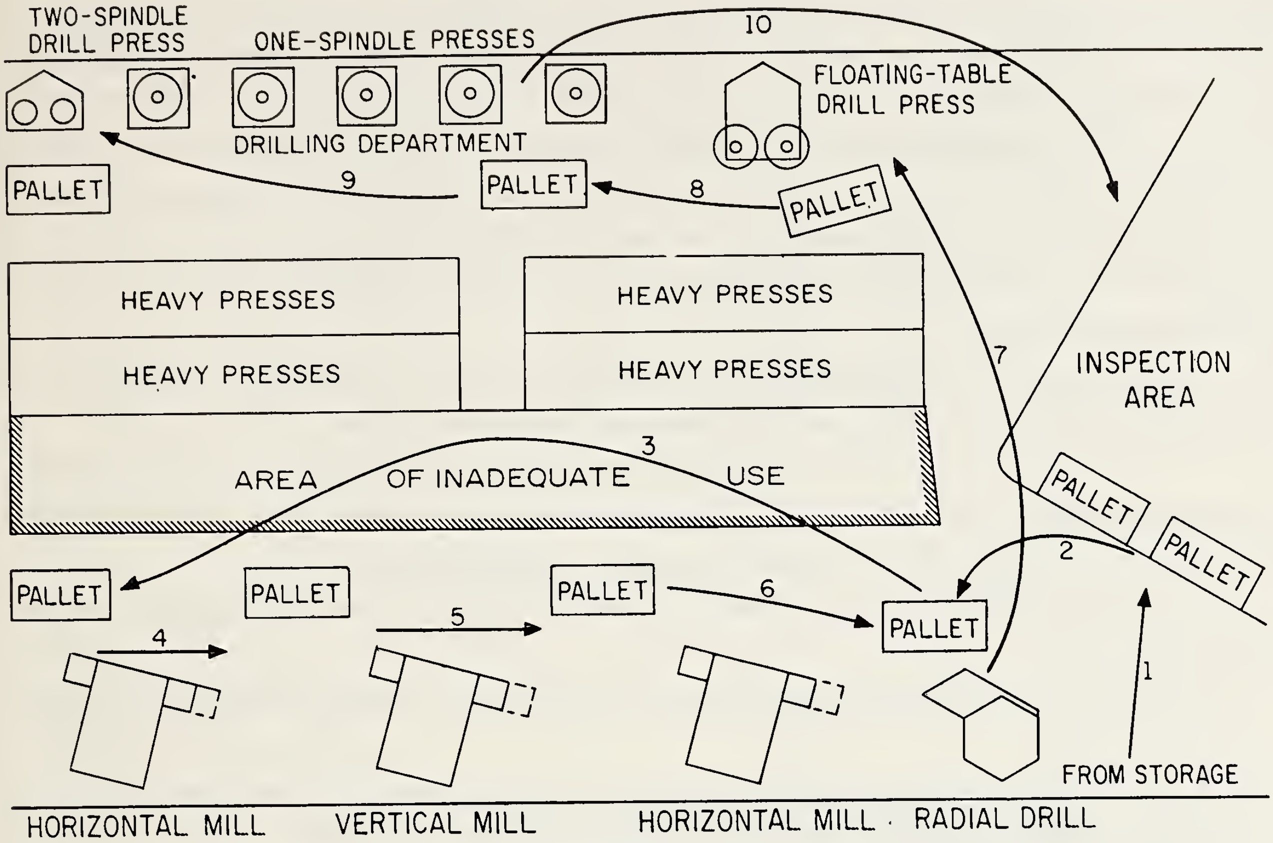


Fig. 2

To visualize the flow of production, the plant layout engineer indicated the general flow of operations with numerically designated arrows.

Questions. In this case the student can see the problems with which the intermittent producer is faced when repetitive-type operations are handled with order-control techniques and a job shop plant layout. The usual analysis (symptoms, causes, and effects) is not necessary because the case indicates what the problem is. The student's task is to make a flow process chart using the following symbols (for further information see text section, Chapter 6):

Transportation ⇨ or o

Operation ○

Inspection ◇

Storage ▽ = permanent
▽ = temporary (for example, pallet full of castings awaiting next operation)

The necessary operations are listed both as descriptive material (see page 236) and as time study data (table on page 235). The descriptive material indicates whether or not operation sequences can be interchanged. What is not apparent from the case is that the company has a limited number of milling machines, one radial drill, one floating-table drill press, one two-spindle drill press, and several other single spindle-drill presses. The case does indicate that these machines must also be used during the month on other jobs as well. Obviously the problem consists of several parts: 1) process analysis, 2) plant layout analysis, and 3) flow analysis. In connection with these problem areas, the student should know that because of the scarcity of equipment, it is essential to strip down the machine before it can be set up for the next operation.

The main task of the student is to find ways and means of saving $15 or more in costs, and the main questions are as follows:

1. How can we save $15 or more by making changes in the production process? In other words, can the sequence of operations be so changed that transportation, setup, and production flow are facilitated?

2. How can a continuous flow between the drilling and tapping operations be established?

3. How can the problems which were outlined during the luncheon meeting be solved?

4. How can milling and drilling operations be synchronized with one another to arrive at a relatively continuous production flow?

5. How many and what kind of employees (skilled, semiskilled, or unskilled) can do the job?

6. Looking at the time study data available, what improvement is immediately apparent as far as production flow and plant layout changes are concerned?

7. Would you say that the milling or drilling machines should be rearranged? (It should be remembered, however, that the radial drill and the milling machines are extremely heavy.)

8. Criticize some of the suggestions indicated in the case.

9. Which suggestion appeals to you?

10. Should the company bid for the repeat order?

11. Assuming an improved production process (and plant layout), at which price should the company bid for the next repeat contract without endangering the company's well being?

NOTE: Question 6 requires some familiarity with the use of time study in production work. Chapter 5 on small business gave some insight into the nature and use of time study in production. What has been said there is pretty much valid in this situation too. However, the student should be able to see the relationship between the *base time* and the various *allowances* which are added to the base time to compensate the worker for certain necessary time losses. The fact must also be remembered that the *standard time* (the time which includes both the first and second allowances in this instance) is always based on the theoretical "normal worker," who in statistics would be the "average worker." Thus, the time, irrespective of whether it is the base time (the time required to do the job including picking the workpiece up and putting it down) or the standard time based on the second or first allowance, represents the time which the majority of workers would need to perform the job in question. The base time is the time which would be needed had the operator worked without interruption by his foreman to give him instructions or without leaving his workplace to drink a glass of water, wash his hands, etc. The second allowance in the case was added to the first allowance because employees had to set up their own machines and carry pallets back and forth as needed. Thus, it was an arbitrarily established figure to make sure that the employees would be compensated timewise for the time they lost from actual production work as a result of handling and setup.

On the time study data shown in the table, it takes, for instance, 1½ minutes to counterbore (operation 18) some holes; 0.17 added to compensate for personal needs make 1.67 (decimal minutes), and another 0.33 to compensate for setup and handling of approximately 150 pieces at a time. (The lot size is approximately 150 pieces, though this rule is not necessarily enforced in this company.)

The total of 2.00 minutes time allowed should be ample to turn out 30 pieces per hour (that is, 60 minutes÷2 minutes=30 pieces). Based on the first allowance only, a maximum of 35 pieces, but at least 30 pieces, was expected per hour (based on the second allowance); yet on the average only 16 pieces were turned out.

Question 6 merely asks whether or not it is peculiar that only 16 as opposed to 30 or 35 pieces were turned out on such a job as operation 18. Thus, what improvements seem desirable to improve production flow and can these changes be made through plant layout arrangements?

6-2. Tropical Shirts Incorporated (Part I)

From humble beginnings, Tropical Shirts Incorporated, of Los Angeles, California, became a fair-sized producer of summer sport shirts. In recent years demand increased gradually as a result both of more leisurely dressing habits in general and the influx of missile and aircraft workers from other parts of the country. These people like to wear shirts without jackets and to dress casually.

The shirts are sold under the trade name Tropical Shirts through various sales outlets such as jobbers, wholesalers, retailers, and swimming pool gift shops. Since the company attributes its success to the popular price of its products, it is essential to keep production costs down despite ever-increasing wage rates, rising materials costs, and inflation. At the same time it is important to maintain quality first of workmanship and second of cloth.

Competition in the shirt business is cutthroat, and any slip in the company's price policy could create serious sales problems. Although over the years the profit margin has become smaller and smaller, the company has remained reasonably successful because its prices continued to suit the pocket of the working population and sales volume rose fast enough to compensate for diminishing profit margins. Fortunately, its customers were not too concerned with the quality of buttons and the number of stitches to the inch. But there are definite limits, for it is essential to maintain a certain amount of strength at the seams. Consequently, in order to keep down production costs and at the same time maintain quality, the process design has had to undergo considerable change to increase employee productivity and company efficiency in general.

Although shirt styles change from year to year, the preponderance of changes occur in the color and gage (thickness) of materials, rather than in the shape and form of the cut itself. Even if changes in style and cut were made, they occurred in cycles and the dies used to cut the material with the cutting press could be used again and again. Similarly, if the production process was once revised and improved, it would not have to be abandoned every time a new style was introduced.

The shirts followed the same production pattern, regardless of model, size, color, or material. A change in the material used affected production costs mainly through higher or lower operating time, but otherwise a changeover made little difference. Shirt production consisted basically of three different activities: 1) cutting the shirt material into component parts, 2) assembly, and 3) pressing (see Fig. 1). Care in cutting had to be taken so that the designs on the finished shirts were even. A sport shirt usually consisted of 12 to 17 parts depending on the number of pockets and the type of sleeve. Since an extra pocket meant extra cost in materials and in the handling, pressing, setting, sewing, and trimming operations, it was reasonable that the company should favor shirts with a left pocket only. However, this was not entirely up to Tropical Shirts Incorporated, because competition always influenced company style policies.

The second phase of production was the assembly process, consisting essentially of a series of stitching operations. Cutout pieces had to be sewn together, buttonholes had to be made, and buttons had to be sewn on. In the past, the number of operations incurred seldom amounted to more than 40. Since it was in the interest of the company to simplify operations as far as possible, each operation consisted of the sewing of a single seam. This allowed the employment of completely unskilled girls who could be quickly trained to do the job. Although most work stations were manned with unskilled employees, at certain production stations it was essential to have skilled help. Even so, each employee could quickly learn every step in the manufacturing process. Consequently, employees learned to produce at amazingly high speeds. Performance varied, of course, with the length of the seam, the nature of material used, the number of stitches to the inch and last, but not least, the skill of the employee.

Fig. 1. Basic steps in shirt production. (Courtesy of Arrow Company, Division of Cluett, Peabody, and Co.)

The third production phase was pressing, with which packaging was also associated. The company production people thought that some savings possibilities lay in pressing, which was done in stages, usually between two stitching operations. Thus, the seam was pressed immediately and the employees worked with well-pressed parts. When the shirt was finally assembled, there was little need for detailed pressing. Finally, the shirts were freed of loose threads, inspected, wrapped, and boxed.

Until recently the company operated with few employees. Each employee knew how to perform at least four or five different sewing operations on different parts of the shirt. The day was divided into four 2-hour periods and in each 2-hour period roughly 120 shirts were produced. Thus the production lot was equal to 120 shirts. This does not mean that every 2 hours 100 to 120 shirts were actually ready and wrapped; it simply means that at the end of the day 400 to 500 shirts were completed. Employees changed their jobs three or four times a day and performed different jobs on the shirts. In this way the company succeeded in keeping the number of employees to a minimum and made the best use of its equipment.

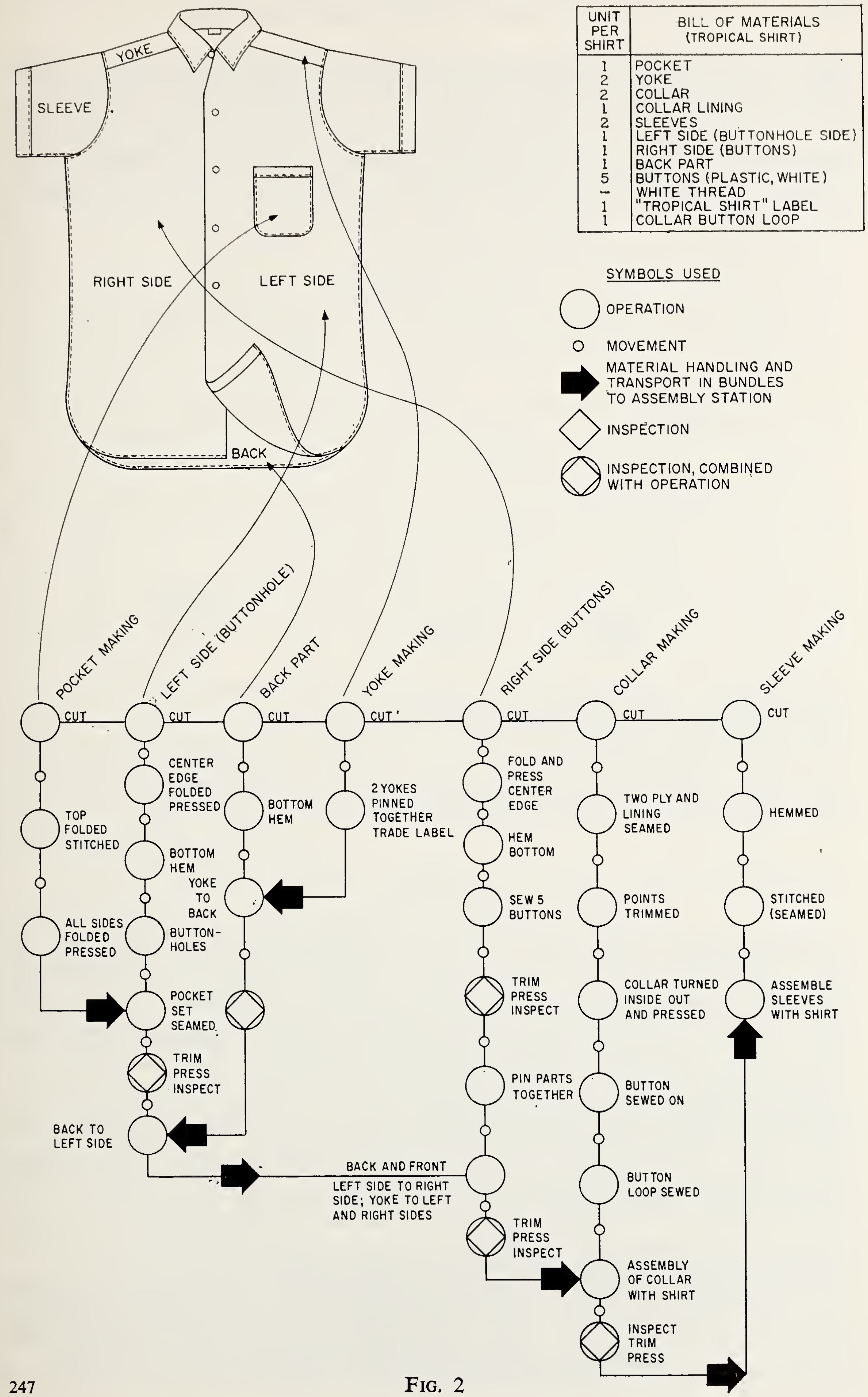
Although the nature of the operation in the Tropical Shirts Incorporated lent itself to continuous production, the company operated as an intermittent job shop. Sizes and other differences created some problems, but production was more or less the same for every item. A consulting firm which offered its services to TSI asked why the company failed to operate by the continuous production method. Company management, however, was of the opinion that no consulting firm could possibly know as much about shirt making as the company.

Time study determined the time for each individual operation. Approximately 20 minutes were required to produce a shirt. This included handling and trimming. The market demand was usually satisfied by 400 shirts or so a day.

Since the employees were limited in number, they were moved around, as needed, at the end of each 2-hour period. As a rule, each employee knew how to sew two or three different seams. The press operator, however, was busy all day long systematically cutting parts with a die. First he changed the pattern and made enough parts to keep employees going for a few hours. Then he punched out certain parts: yokes, collar parts, front ends, pockets, sleeves, etc.

The company's operations were relatively inefficient because the same employees sewed several different seams during the day. The chart in Fig. 2 shows the process flow. The pockets were folded and then sewn in two operations. The left side was hemmed, buttonholed, and side-seamed with the back, and then the yoke was sewn to the left front end. The right side was similarly treated, except that buttons were sewn on instead of buttonholes made. The back part was hemmed at the bottom, sewn to both front sides, then to the yoke. The sleeves were hemmed, seamed, and sewn into the shirt. The yoke was cut, and two yokes were assembled and a "Tropical Shirts" label was sewn on them. The buttonhole loops were made separately by sewing a long seam, turning it inside out, pressing, and cutting it into the appropriate length. The collar was cut by the press (150 sheets of material were layered together just like a series of sandwiches—the lining between the two pieces of shirt material) then it was sewn as indicated by the process sheet, Fig. 1, and finally assembled with the shirt.

The general process of shirt assembly can be divided in different ways depending on the way the company arranges its plant facilities and on the number of persons it wants to employ. After the pieces of a sport shirt are cut



UNIT PER SHIRT	BILL OF MATERIALS (TROPICAL SHIRT)
1	POCKET
2	YOKE
2	COLLAR
1	COLLAR LINING
2	SLEEVES
1	LEFT SIDE (BUTTONHOLE SIDE)
1	RIGHT SIDE (BUTTONS)
1	BACK PART
5	BUTTONS (PLASTIC, WHITE)
–	WHITE THREAD
1	"TROPICAL SHIRT" LABEL
1	COLLAR BUTTON LOOP

Fig. 2

(Fig. 3), each piece is notched (the notches are little markers that indicate where two parts must be fitted together). In a similar manner, the seam-line ends, the buttonhole locations, the top of the sleeve, the center front, the lines of sleeve openings, and many other details are carefully indicated and each part goes to the work station where the respective operation is going to be performed.

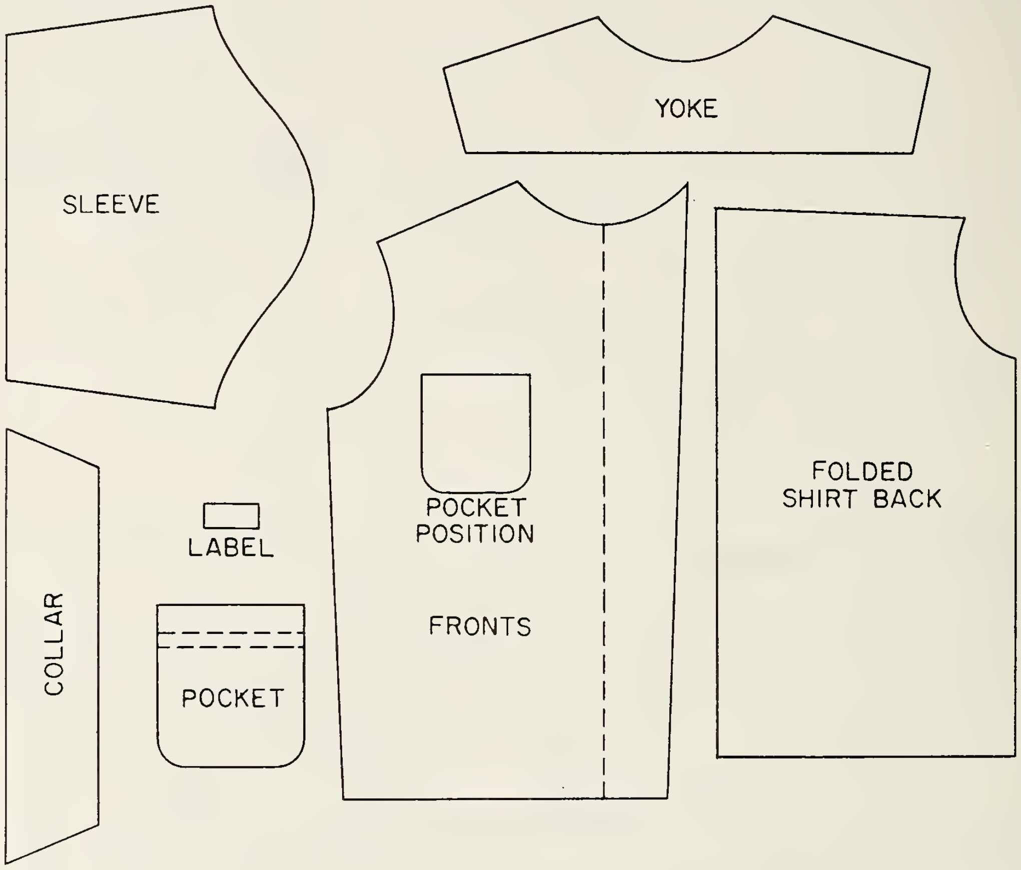


Fig. 3

The employee handling the front units knows that the neckline and the neck edge of the facing extension from shoulder to center on the seam line must be stay-stitched. The pocket is pressed under about ¼ inch on the upper edge; then it is turned to the outside along the fold line to form the hem facing. Commencing at fold, the employee makes a stitch on a seam line around the pocket; finally, she trims the seam and corners. Unless the back is straight, the employee working on the back makes two rows of machine gathering on the upper edge of the shirt back between the prepunched notches. Then she puts the first row on the seam line and the second row ¼ inch from the first on the seam allowance. As all parts are prepared for assembly, the individual operators sew two or more parts together in a predetermined manner.

The company employed 20 female workers who operated sewing machines and steam irons, inspected, trimmed the threads off, sewed buttons, made buttonholes, and so on. The average wage rate was $1.50, but it varied from $1.35 to $1.55. Since it was an open shop, the employees were not members of any labor union. Though the Amalgamated Clothing Worker's Union made several unsuccessful attempts to organize the company, it did not succeed, primarily because the labor turnover was very high.

Questions. The Tropical Shirts Incorporated case indicates a planning problem which when successfully solved can influence the company's production and determine its profit-making ability. Although not apparent from the case, the task is to establish a process design which will allow production of twice as many shirts in the same production time. (For more information the interested student should read Case 7-2, part II of the Tropical Shirts Incorporated case.) The present process is not perfect, but this is what the student must study and improve.

Since the company is not in trouble at present, the usual method of determining symptoms and causes is not necessary. It is necessary, however, to be ready with a decision, since in the future the sales volume is expected to double but the cost of production must be kept in line with the prices of larger producers in the country. Right now, the company has a much smaller profit margin than that of comparable producers. New York producers spend no more than 10 minutes per shirt, while Tropical Shirts Incorporated spends 20 minutes. The problem can be thought of as a comparative problem rather than an actual one.

1. Check the process sheet of Tropical Shirts Incorporated and determine whether or not improvement in the process is possible. a) Can the productive steps be arranged in better order? b) Can the productive steps be reduced, combined, or eliminated? c) Are the steps in the production process as economically arranged as possible? d) Can transportation and extraneous materials handling be eliminated?

2. How could the company convert its production from the present intermittent process to a more continuous production flow?

3. Look at the problem from a different point of view: could operations be subdivided into smaller steps?

4. Is the "bundle system" (that is, 120 shirts per 10 bundles) useful when the company attempts a production-line type of operation?

5. Draw up a process flow chart indicating your suggested method.

6. State precisely why you think that your method of producing the shirts (as indicated in the answer to the preceding questions) is better than the method in use at the moment.

7. Which operations would you relocate or interchange to make the production flow smoother?

8. Check the time study data in Case 7-2, part II of the Tropical Shirts Incorporated case, and, by taking the time study data into consideration, indicate a possibly better production flow.

9. Can the operations be synchronized with one another?

10. If your method requires more equipment, indicate the approximate amount required.

11. Use the plant layout in Fig. 4 as your guide and determine an improved plant layout for Tropical Shirts Incorporated.

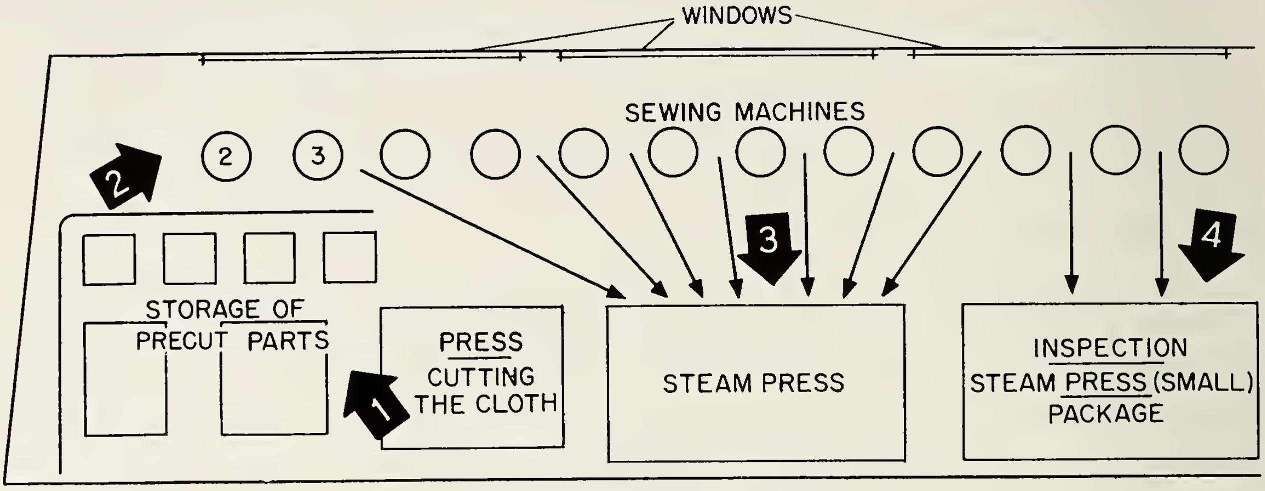


Fig. 4

6-3. National Home Supplies, Inc.

The company is engaged in the production of kitchen and bathroom equipment. Plant activities consist of machine shop work, cabinetwork, assembly and painting (including enamel firing), and inspection, which originally took place in a centralized inspection booth next to the machine shop and the cabinetworks. Only inspectors were permitted inside the booth; parts were placed on incoming shelves, and inspected workpieces were placed on the opposite side of the booth marked either "O.K." or "Return to Mr. X." By this method, crowding and confusion within the booth were eliminated. Inspectors were provided with a bench as well as with all sorts of inspection tools and instruments. Furthermore, the company management was of the opinion that losses were fully eliminated and production flow was controlled, since every item had to be carried to the inspection department before it left the plant. Quality control in this company was typically a 100% inspection.

Since the company produces kitchen and bathroom equipment to customers specifications, most products have to be approved by inspection. As a rule, the completed kitchen or bathroom sets leave the company premises as parts. They are sent to the construction site, where plumbers or assemblers put them together. The company has production contracts with local building contractors and undertakes to produce the bathroom or kitchen to the home buyer's prescription. The home buyer supplies his general idea and National Home Supplies engineers formalize the blueprint which subsequently has to be approved by the customer and the building contractor. With their approval, National Home Supplies, Inc. starts production of the bathroom parts.

As a rule, these parts are of excellent fit and few problems are experienced. But with a building boom and an unprecedented growth of the market for custom-made kitchen and bathroom equipment, assembly difficulties developed. Parts of inferior quality reached the assembly site, and the blame was put on the inspection department. When the part had gone through all the necessary productive steps, the operator who performed the last operation had taken it and the blueprint to an incoming shelf of the inspection department. When an inspector in the inspection booth became free, he would go to the shelf, pick up any one of the workpieces awaiting inspection, and check dimensions, interchangeability, tolerances, joints, surfaces, etc. All inspectors were skilled men and worked independently. In view of the difficult nature of inspection in National Home Supplies, Inc., inspectors were paid anywhere from $450 to $600 per month.

With the sudden increase in business, the output of the production departments also increased and the shelves were always full. The inspection department constantly had more work than it was capable of handling. Thus, inspectors began to work too fast, and many defective workpieces were passed. When subsequently the parts were assembled at the building site, the fit was frequently far from perfect. Generally speaking, workmen at the site can adjust the kitchen or bathroom equipment and even make some structural changes to fit it, but then the plumbers and masons have to spend extra time on finishing the house. In other words, overhurrying in the National Home Supplies inspection department created problems in the construction of the houses. As far as the building contractors were concerned, this meant more assembly time and higher labor costs amounting to $100 to $150 or more per house. Contractors therefore began to complain to the management of National Home Supplies.

When complaints became frequent, management assigned an industrial engineer to investigate the situation. According to his report, there were two solutions: 1) to hire more inspectors as well as to increase the work area of the inspection department and 2) to decentralize inspection. It seemed possible to build inspection stations into production lines provided that, despite intermittent production, definite lines of production flow prevailed.

Since the industrial engineer's suggestions had merit, production executives authorized the engineer to make further investigations. This authorization was prompted by the fact that management could not afford extra inspectors at their original salary scale. If, through a decentralized inspection, inspection work could be made easier, both a cost reduction and an improvement of quality could be achieved.

The industrial engineer's approach to this problem consisted of the following three steps:

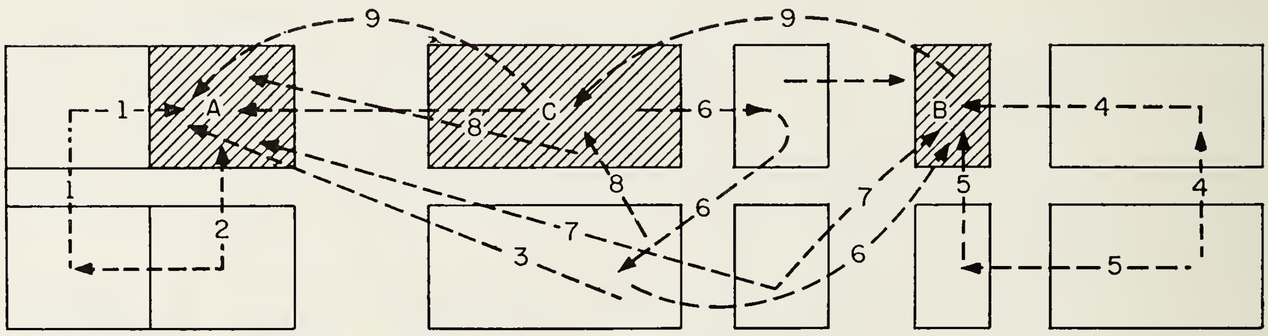
1. Collection of inspection records for the past 4 years and the classification of defects according to department of origin

2. Collection of all available bills of material and the classification of component parts into a) standard items used in most products, b) nonstandard items with some degree of similarity to one another, and c) items unique to individual orders
3. Collection of process sheets for every item listed above and the classification of the production flow according to flow patterns

The results obtained indicated, for instance, that defects in shearing in the machine shop are almost always either short cuts or off-center cuts. Therefore, the engineer concluded that an inspection station after the shearing machine might catch the trouble at its source.

An inspector checking only one aspect of the job does not need to know everything about inspection and blueprint reading. Anybody with average intelligence and a knowledge of one or two dimensions and measuring technique could be trained for inspection jobs of this kind and employed for $240 per month.

Bills of material and process sheets revealed to the engineer the general flow of production on differently classified items. This resulted in the establishment of strategic points where inspection stations could be installed. The production flow is shown in the accompanying illustration.



A and B are well-frequented departments through which most orders pass.

The industrial engineer established an inspection station where the nature of operations required one and where the probability of defective production was high. He investigated the cost of a given operation and placed an inspection station in front of a high-cost station so that further work on an already defective workpiece could be prevented. For example, he placed an inspection station before the painting station because painting could conceal a defect and make repairs costly.

Eventually, the industrial engineer convinced management of the advisability of his plan and the original inspection booth was taken away to free space for production purposes.

Questions. This case illustrates process design per se and shows how the inspection department should be handled. It is apparent from the case that in this company the solution to the quality and cost problems lies in a process design in which inspection stations are placed in their proper sequence. In addition to the changing over from central inspection to decentralized inspection, this may require a rearrangement of plant facilities. Although it is not essential to go through the normal question procedure (symptoms, causes, solution), the student by doing so can test whether the industrial engineer has pursued the right course of action.

1. Comment on the activities of the industrial engineer.
2. Did he approach the problem properly?
3. Determine whether the investigations he made would result in information necessary to setting up a new and improved production process guaranteeing higher quality at lower costs.
4. What are the benefits, if any, of decentralized inspection as opposed to centralized inspection?
5. In intermittent production such as that engaged in by National Home Supplies, Inc. is it possible to have some sort of line layout of facilities into which inspection departments can be integrated on a decentralized basis?
6. Explain and justify the industrial engineer's approach. Show the probable results of this kind of investigation.

chapter 7

Methods Planning for Intermittent Production

Since production efficiency depends largely on the excellence of the production process, it is only natural to direct attention next to the perfecting of the process and the motions involved in the various operations. Accordingly, subsequent to the process planning comes methods planning. It is nothing more than the implementation of the original processing decision.

Being a supplementary function, methods improvement consists of careful reconsideration of the production process while still in the planning stage or immediately after it is put into practice with the intention of finding and eliminating flaws. But probably the most important aspect of methods engineering is detailing the various work stations involved in the production process and reducing them to precise hand motions. In other words, work station arrangement, hand motions, and man and machine relations are developed and implemented by methods men who thereby lay the foundations of both performance control and production control. Obviously, precise work measurement must be made in order to establish the time required for individual operations and a schedule for the production process as a whole. The latter would be difficult (or useless) unless prior to time study the methods were well designed. The resulting time standard will then be employed both in production and in performance control.

It should be well understood, however, that the degree of perfection needed in methods and processes depends largely on the size of the production volume. In the typical job shop where relatively few pieces are produced, an extensive and time-consuming methods study may be wasteful in the sense that the time and effort spent on the study cannot be recovered. Whereas in large-scale production every little improvement counts, in intermittent production it is worthwhile to introduce only the major improvements. Hence, in the latter case, often only a cursory study is warranted and a little inefficiency may cost less than a time-consuming study by high-paid experts.

Accordingly, the original process sheet is merely a first draft, so to speak; and before the go-ahead is given, other experts may criticize and improve the method. Also, since time study is needed to provide management with information about time requirements for both the scheduling of operations and the process as a whole, methods study may have an important by-product in that it standardizes the work and thereby assures a greater validity of the time standard.

That time plays an important role in production planning work goes without saying, but that there is a relationship between methods and the time factor must be further elaborated. For the sake of understanding, it should be noted that methods are often improved through careful coordination of men and their machines, that is, coordination of left-hand motions with right-hand motions and the machine which may be involved. Thus, in order to better synchronize human motions with mechanical devices and with one another, it is essential to appraise human motions with respect to the time factor.

In a chronological order, then, the original process planning is followed up by 1) methods planning and 2) work measurement. The two are complementary; they are also related to process and plant layout designs and are the foundation of production control. Indeed, the above-mentioned functions are so interwoven that it is difficult to distinguish where one type of planning activity stops and the other begins. One element common to the planning activities is that they all depend on the availability of a predetermined production process. Were these preliminary activities not performed with appropriate care, the resulting planning work would suffer. It must be apparent that production control can contribute to efficient operations only if the process of production is developed with care, if the time study data are correct, and if employees perform in accordance with the standard requirements.

All in all, before effective production can take place, the production department must learn from a series of other specialized departments what must be done, where it must be done, how it must be done, and how long it will take. These preliminary problems and questions are answered by the methods and industrial engineering group.

PROCESS IMPROVEMENT

More heads know more! The process engineering group cannot look into the matter of efficiency with sufficient care. On the other hand, the methods study experts are employed precisely for the purpose of analyzing the methods with improvement in mind. The skilled process planners will solve the technical problems with a great deal of competence, but they might overlook certain details. However, the flaws which methods planners find in the process seldom originate from technological imperfections, but are due mainly to oversight. That being true, they can be corrected by mere rearrangement of workplaces and reshuffling of operations or by purposefully changing the sequence of operations, the hand and body motions, etc. In other words, the methods planners look at the methods not so much from the technical point of view as from the viewpoint of wasted motions, unnecessary movements, illogical arrangements of men and machines, and many other pitfalls involved in the job.

The production process can be considered as being improved either when the unit costs are successfully reduced or when the quality is enhanced without additional monetary investment. As said before, improvement may result not from earth-shaking innovations but from minor details which otherwise tend to be overlooked. A careful and systematic observation can usually reveal all sorts of shortcomings. A methods man may ask himself some of the questions which are summarized here under four groups:

1. Are all operations on the process sheet necessary? If so, can some of them be combined? Must the various steps be performed in the specific order given on the process sheet? If not, would reshuffling operations facilitate some of them or even eliminate some of them? At least, could one step be performed as an integral part of another one and thereby eliminate transportation and additional handling?

2. Is it necessary to adhere to the design specifications to the letter or would it be permissible to make minor design changes which, in turn, would facilitate production and cut both time and cost requirements? Would a change of raw material be permissible to the ultimate end of reducing the number of steps or using different equipment altogether? To what extent is deviation from tolerance requirements permissible? (This may have possibilities similar to the use of different raw materials.)

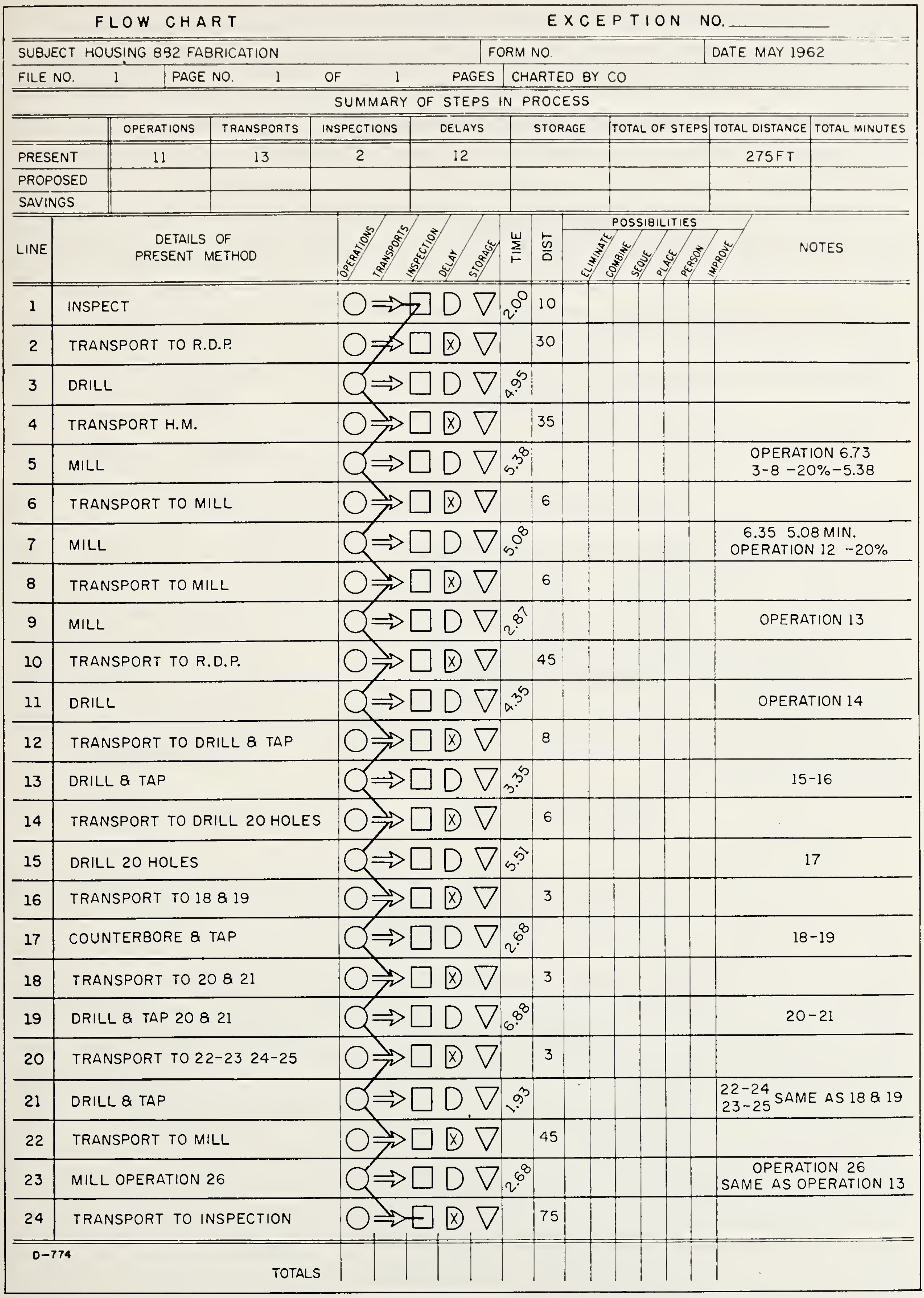
3. Can the tools, equipment, and materials-handling devices be changed to permit savings in costs per unit of output? Can the workplace, including the tools used, be so rearranged that work performance is facilitated and the time requirement is reduced?

4. Can the motion pattern be rearranged to avoid idle hand motions, holding something which could be held by holding device, or using feet rather than hands? Can the motion pattern be so arranged that the hands work alternately rather than having one hand overloaded with work while the other hand is largely idle? Can the hand motions be made simultaneously rather than out of phase? Can the motions of hands or feet be synchronized so that a machine operator can serve several semiautomatic machines? Can the motions of several men be correlated to get better overall results?

REASONS FOR CHARTING

Methods men use charts to facilitate the procedure of analysis and planning. All sorts of charts have been developed to depict various performances in a simplified manner. For example, production processes, continuous or repetitive, are analyzed with process flow charts, Fig. 7-1[1]; work stations are analyzed with operation charts or with men-and-machine charts, depending

[1] On the upper left-hand corner of Fig. 7-1, an abbreviated analysis technique says why, what, where, when, who, and how the process is carried out. The summary of the process in question reveals that there are 11 work stations, 13 transportations, 2 inspections, and 12 delays. These data beg the questions whether the above can be reduced,



FLOW CHART EXCEPTION NO.________

SUBJECT HOUSING 882 FABRICATION	FORM NO.	DATE MAY 1962
FILE NO. 1	PAGE NO. 1 OF 1 PAGES	CHARTED BY CO

SUMMARY OF STEPS IN PROCESS

	OPERATIONS	TRANSPORTS	INSPECTIONS	DELAYS	STORAGE	TOTAL OF STEPS	TOTAL DISTANCE	TOTAL MINUTES
PRESENT	11	13	2	12			275 FT	
PROPOSED								
SAVINGS								

LINE	DETAILS OF PRESENT METHOD	OPERATIONS	TRANSPORTS	INSPECTION	DELAY	STORAGE	TIME	DIST	POSSIBILITIES						NOTES
									ELIMINATE	COMBINE	SEQUE	PLACE	PERSON	IMPROVE	
1	INSPECT	○	⇒	□	D	▽	2.00	10							
2	TRANSPORT TO R.D.P.	○	⇒	□	(X)	▽		30							
3	DRILL	○	⇒	□	D	▽	4.95								
4	TRANSPORT H.M.	○	⇒	□	(X)	▽		35							
5	MILL	○	⇒	□	D	▽	5.38								OPERATION 6.73 3-8 −20%−5.38
6	TRANSPORT TO MILL	○	⇒	□	(X)	▽		6							
7	MILL	○	⇒	□	D	▽	5.08								6.35 5.08 MIN. OPERATION 12 −20%
8	TRANSPORT TO MILL	○	⇒	□	(X)	▽		6							
9	MILL	○	⇒	□	D	▽	2.87								OPERATION 13
10	TRANSPORT TO R.D.P.	○	⇒	□	(X)	▽		45							
11	DRILL	○	⇒	□	D	▽	4.35								OPERATION 14
12	TRANSPORT TO DRILL & TAP	○	⇒	□	(X)	▽		8							
13	DRILL & TAP	○	⇒	□	D	▽	3.35								15-16
14	TRANSPORT TO DRILL 20 HOLES	○	⇒	□	(X)	▽		6							
15	DRILL 20 HOLES	○	⇒	□	D	▽	5.51								17
16	TRANSPORT TO 18 & 19	○	⇒	□	(X)	▽		3							
17	COUNTERBORE & TAP	○	⇒	□	D	▽	2.68								18-19
18	TRANSPORT TO 20 & 21	○	⇒	□	(X)	▽		3							
19	DRILL & TAP 20 & 21	○	⇒	□	D	▽	6.88								20-21
20	TRANSPORT TO 22-23 24-25	○	⇒	□	(X)	▽		3							
21	DRILL & TAP	○	⇒	□	D	▽	1.93								22-24 23-25 SAME AS 18 & 19
22	TRANSPORT TO MILL	○	⇒	□	(X)	▽		45							
23	MILL OPERATION 26	○	⇒	□	D	▽	2.68								OPERATION 26 SAME AS OPERATION 13
24	TRANSPORT TO INSPECTION	○	⇒	□	(X)	▽		75							
	TOTALS														

D-774

FIG. 7-1. Process flow chart.

on the use of hand tools or machines. If several machines are operated by a worker, multiactivity charts are used. If the operation deals with extremely small motions, such that every tiny improvement may count, a simo-chart may be used to analyze the job in question. (The fact that a simo-chart is based on micromotion study makes it almost exclusively a tool of large-scale production.)

Obviously, if one had a photographic mind, no chart would be needed to remember a process or operation with a view toward improving its various components. But most of us are better off when we jot down our observations; we thereby record details and acquire the basis for an overall view. No one should imagine however, that charts by themselves improve anything; they merely aid in the process of analysis. Ingenuity is what improves a process, operation, or work station of any kind.

The kind of charts methods men use and the kind of diagrams they draw up as devices of observation is immaterial in the sense that the charts are merely aids and not improvements in themselves. Nevertheless, charts are used to illustrate what goes on and point up the pitfalls of operations. The chart may, like shorthand, seem unintelligible to anyone unfamiliar with the symbols used. In practice, certain standard symbols have been developed for given production situations. However, any symbol is equally useful provided the user can make it out and visualize what the chart purports to show. The standard symbols used in these charts will clearly indicate the present method and can also be used to depict a new, improved method. These symbols are illustrated in Fig. 7-2.

THE WORK STATIONS

Unless they are repetitive, most job shop operations do not warrant the time-consuming scrutiny which is being explained here. Nevertheless, some of the same considerations can be given quickly. An experienced methods man may be able to improve work flow and performance at a work station without a great deal of study. The financial benefits which ordinarily should follow come from speedier performance, better use of both unskilled and skilled labor, and better use of production or materials-handling equipment. Furthermore, the flow of production may be made more even, thereby reducing the neces-

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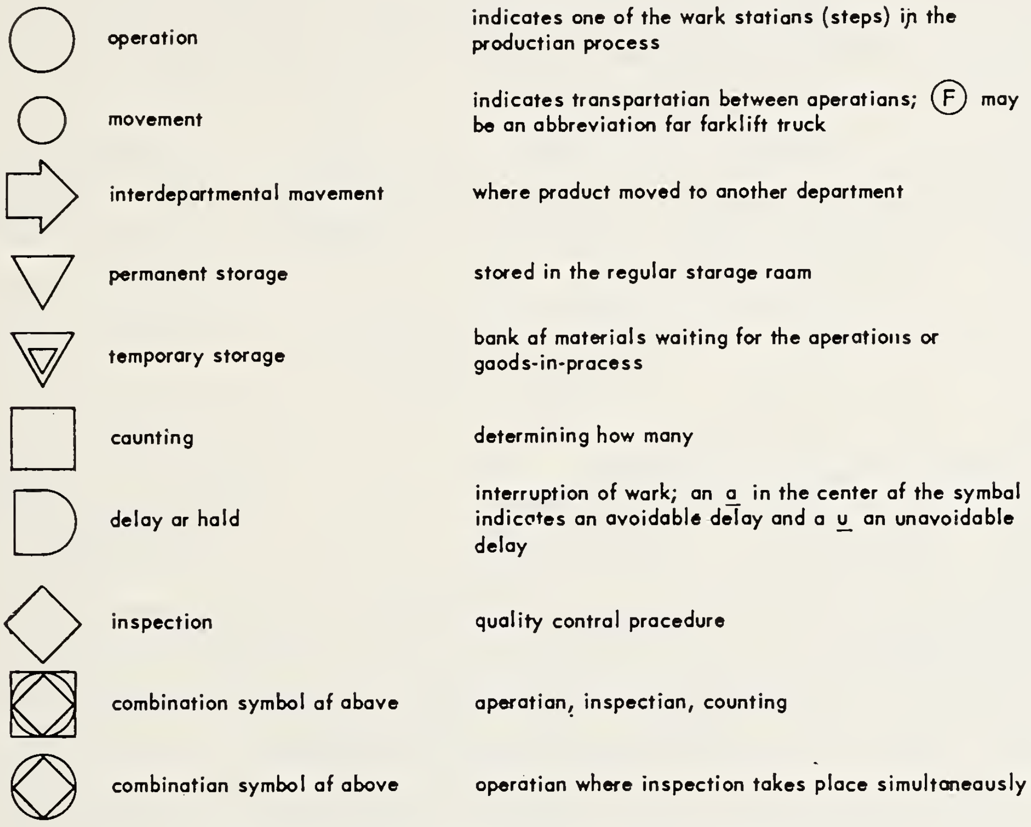
combined, or otherwise eliminated and whether or not the transportation distance of 275 ft can be reduced.

The objective of such a process flow analysis is, of course, to streamline the process, reduce the number of steps to the minimum as long as they are commensurate with production requirements. Apparently, we are dealing with an intermittent job shop and some of the transportation needs result from the plant layout arrangements. Whether the departmental movements can be reduced or changed depends on whether the operations can be reshuffled so that two operations using the same type of equipment can be performed consecutively. The delays which tend to develop in conjunction with transportation may give a clue to some pitfall preventing a smooth flow between operations. Of course, further investigation is necessary, and it may disclose whether the delay is inherent in the transportation or is avoidable.

sity for temporary storage or longer than necessary tie-up of working capital.

Whether production is intermittent, repetitive, or continuous, there is a relationship between output of departments, machines, and work centers. Unless all the plant facilities are able to handle approximately the same work load, there will be an imbalance in the layout and bottleneck stations will develop. The consequences are costly slowdowns. Searching out these imbalances may also be a function of process improvement; accordingly, plant layout work has a great deal to do with methods study. Furthermore, time study may be necessary because in machine shops, for instance, capacity is expressed in time. The output capacity of a milling machine varies with the length of time any given work requires. A 2-minute operation will cut capacity to half in comparison with another operation which takes 1 minute. Thus, methods study may get into plant layout work or time study may be connected with methods study as well as plant layout work. Often one cannot tell where methods study ends and plant layout work begins; one shades into the other. The point of departure is the original process, but there will be divergence by gradual steps into related industrial engineering activities.



operation	indicates one of the work stations (steps) in the production process
movement	indicates transportation between operations; Ⓕ may be an abbreviation for forklift truck
interdepartmental movement	where product moved to another department
permanent storage	stored in the regular storage room
temporary storage	bank of materials waiting for the operations or goods-in-process
counting	determining how many
delay or hold	interruption of work; an a in the center of the symbol indicates an avoidable delay and a u an unavoidable delay
inspection	quality control procedure
combination symbol of above	operation, inspection, counting
combination symbol of above	operation where inspection takes place simultaneously

FIG. 7-2. Standard flow-chart symbols.

It must, then, be clearly understood that process engineering, methods study work, time study, and plant layout considerations are not always fully separable from one another, because they are all concerned with problems aiming at improving production efficiency. All these activities are planning activities, and they are all ultimately related to production control work.

The flow of production in job shops is quite different from that in mass-production enterprises. In the former, there is a gradual movement from the receiving room toward the shipping room all the time, but this movement must be established artificially through the scheduling procedure. Scheduling, in turn, requires the process and time study information. In job shops the process improvement more or less consists of combining operations and thereby eliminating extra handling and transporting materials from one department or machine to another, of choosing a better means of transportation, and possibly of changing the sequence of operations so that the overall result can be attained in a manner that is more favorable from the standpoint of quality or cost. Again, time study is important, because time study can tell how long the various machines involved in the production process will be tied up.

Regardless of whether it is done in job shops or in continuous mass-producing enterprises, methods study is nothing more than organized common sense directed toward improving or eliminating motions considered inefficient. Whether hand motions or long hauls are the subject matter of the improvement is in fact immaterial. Any elimination of motion or movement will result in time savings, and savings in time usually mean savings in money also. This kind of work requires industrial engineering personnel to be alert to costs and the various sources of inefficiency. An inquiring and open mind combined with technical know-how are usually the essential ingredients. When they are present, the study of operations tends to lead to improvements.

Where the operations may go unchanged for years or where the saving of a few seconds may mean perfecting the flow of operations in a conveyorized system, the motion analysis may require the most exacting type of motion study. Since the overall savings are dependent on a few selected work stations, the expenditure of large sums of money to perfect the output rate of stations where bottlenecks may otherwise develop may be warranted. Here, it may even pay to employ the so-called micromotion study, Fig. 7-3.

It should be understood that methods planning is done in stages. First, the production process as a whole is analyzed. This could be illustrated as in Fig. 7-3. After the best production process is developed, the individual work stations are analyzed to see if some of the operations can be improved, Fig. 7-4. Whereas in process planning it is possible to eliminate a whole step (that is, an operation), combine two or three operations, or shuffle the sequence in which the operations are performed, in methods planning only the workplace itself is considered. The effort is to design the workplace to get better mileage out of both the operator and his machine. The attempt may consist of eliminating unnecessary motions the worker may make by following an unscientifically designed method or improving on an unwise arrangement of the tools and other items with which he works. In either case the attempt is to make the work easier and faster. When the employee works with a

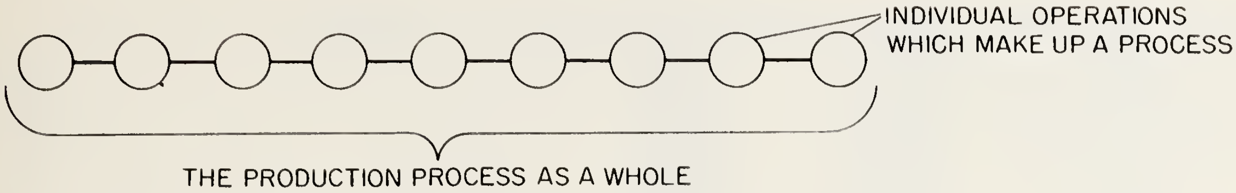
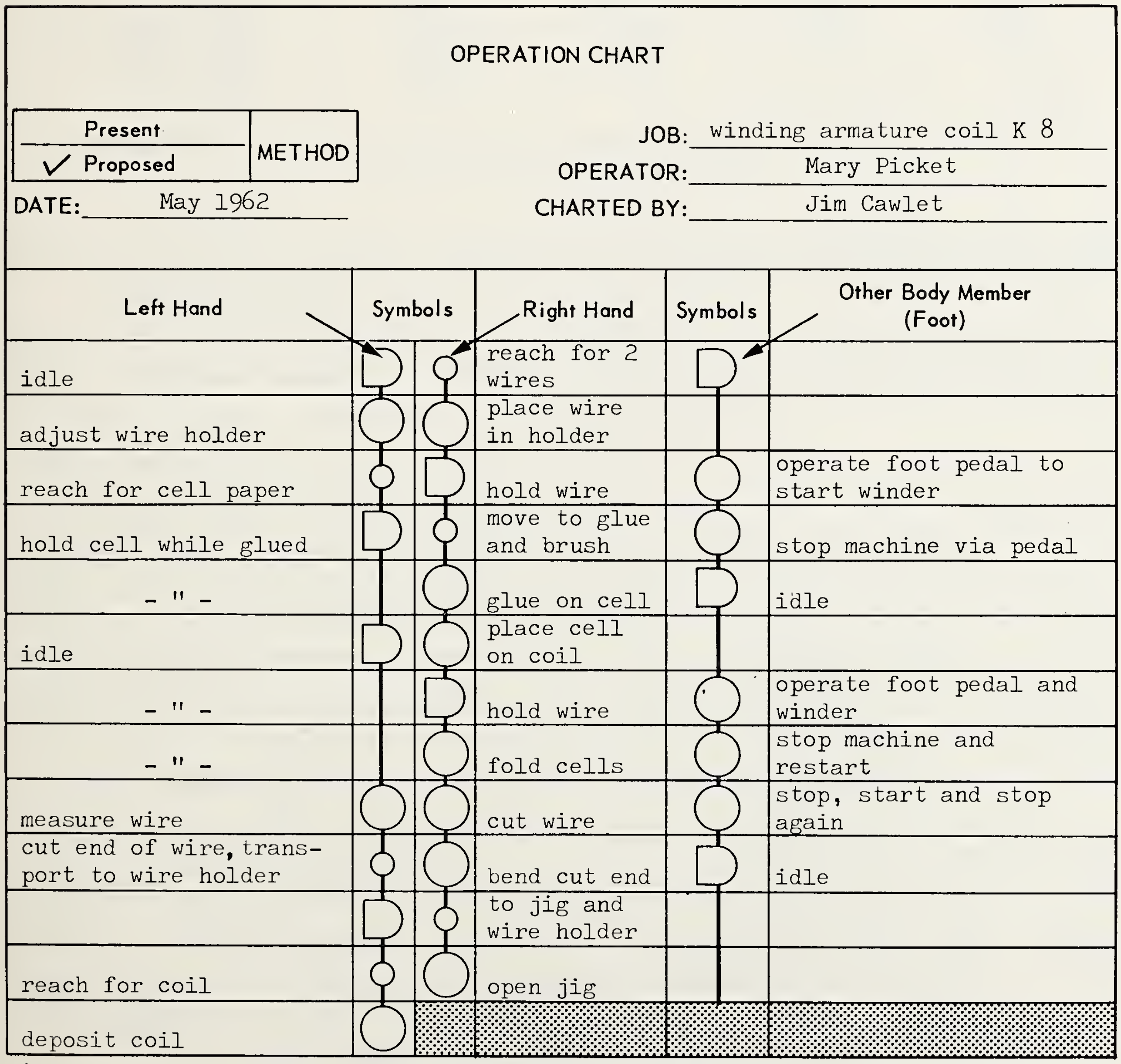

INDIVIDUAL OPERATIONS WHICH MAKE UP A PROCESS
THE PRODUCTION PROCESS AS A WHOLE

FIG. 7-3.

semiautomatic machine, it is conceivable that half of his time is spent idly waiting for the automatic part of the work cycle to be completed. In such instances, the improvement may come from synchronizing the various phases of his work so that he can run two or three machines simultaneously, Fig. 7-5. Of course, to be able to design the work so well that such an excellent utilization of the employee on a given job can be attained, it may not be enough to use visual observation; the human eye may not be able to catch all the little details which may be significant in designing a better and more economical



OPERATION CHART

Present ✓ Proposed	METHOD

DATE: May 1962

JOB: winding armature coil K 8
OPERATOR: Mary Picket
CHARTED BY: Jim Cawlet

Left Hand	Symbols		Right Hand	Symbols	Other Body Member (Foot)
idle	D	∘	reach for 2 wires	D	
adjust wire holder	○	○	place wire in holder		
reach for cell paper	∘	D	hold wire	○	operate foot pedal to start winder
hold cell while glued	D	∘	move to glue and brush	○	stop machine via pedal
- " -		○	glue on cell	D	idle
idle	D	○	place cell on coil		
- " -		D	hold wire	○	operate foot pedal and winder
- " -		○	fold cells	○	stop machine and restart
measure wire	○	○	cut wire	○	stop, start and stop again
cut end of wire, transport to wire holder	∘	○	bend cut end	D	idle
	D	∘	to jig and wire holder		
reach for coil	∘	○	open jig		
deposit coil	○	▨	▨	▨	▨

FIG. 7-4. Operation chart.

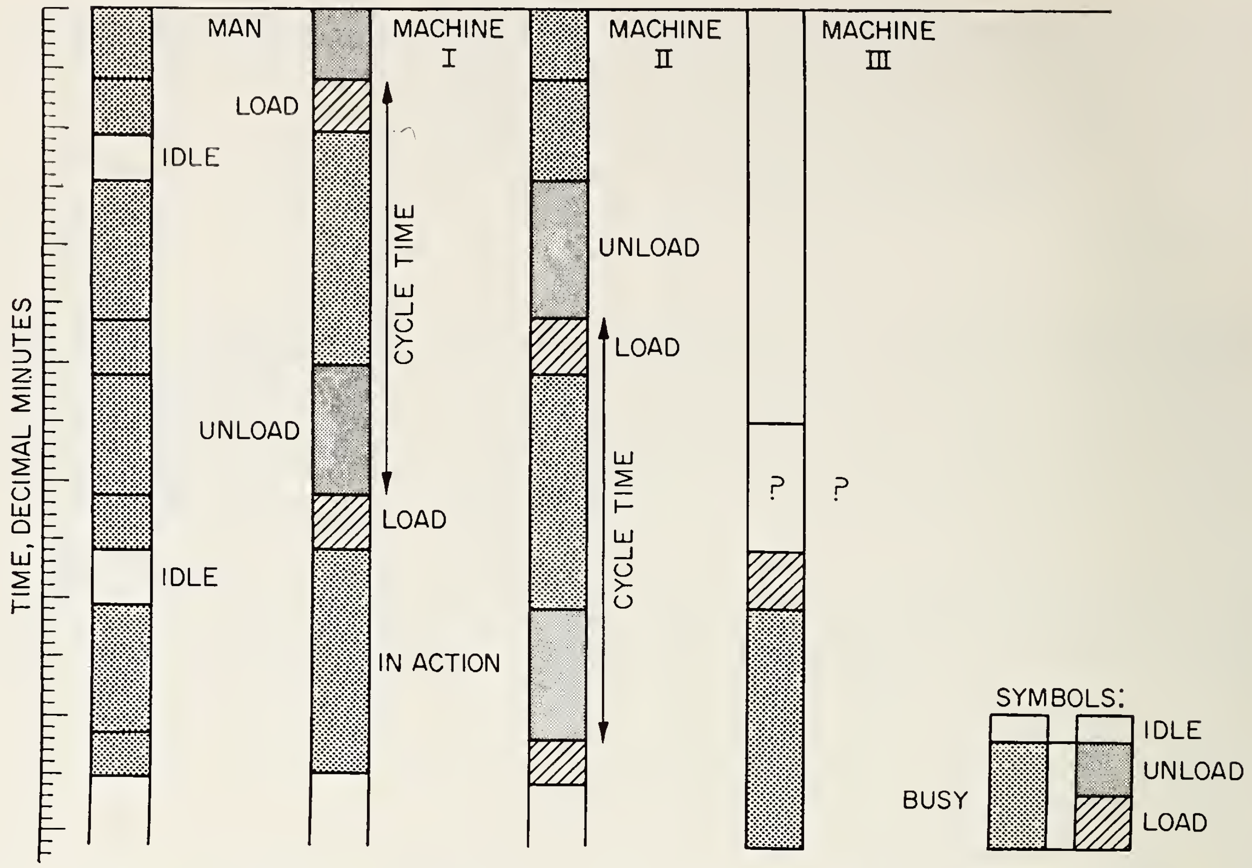


FIG. 7-5. Multiactivity chart. (Question mark indicates inability to synchronize work and time to operate a third machine.)

way of performing the operation or operations. This is where the motion analysis has recourse to the high-speed camera and micromotion study:

The operation can be studied either by visual observation or by using a high-speed camera. The function of the camera is simply to replace the visual observation part of the work. Ultimately, the observations must be charted in the same manner as before. These special cameras can take two or three times the normal number of frames per minute so that, when the film is run back at normal speed, the operation can be studied in slow motion. Because of the slow-motion presentation, many little motions that otherwise would escape the attention of the motion study expert can be observed. It must be apparent by now that the micromotion study differs only in method from the visual observation. The charting procedure remains the same as if a live performance was observed. Although in a sense we draw up an operation chart, the resulting chart, to distinguish it from the operation chart, is called a simo-chart.

The process design may take two different forms. One may start with observation of the process as a whole and conclude at the specific work stations; the other may start with the work stations and build up the production process. The result in either case is an improved production process. The first method of improving processes is better for intermittent job shops because the relationship between operations is otherwise difficult to visualize. The latter method is more applicable to continuous production.

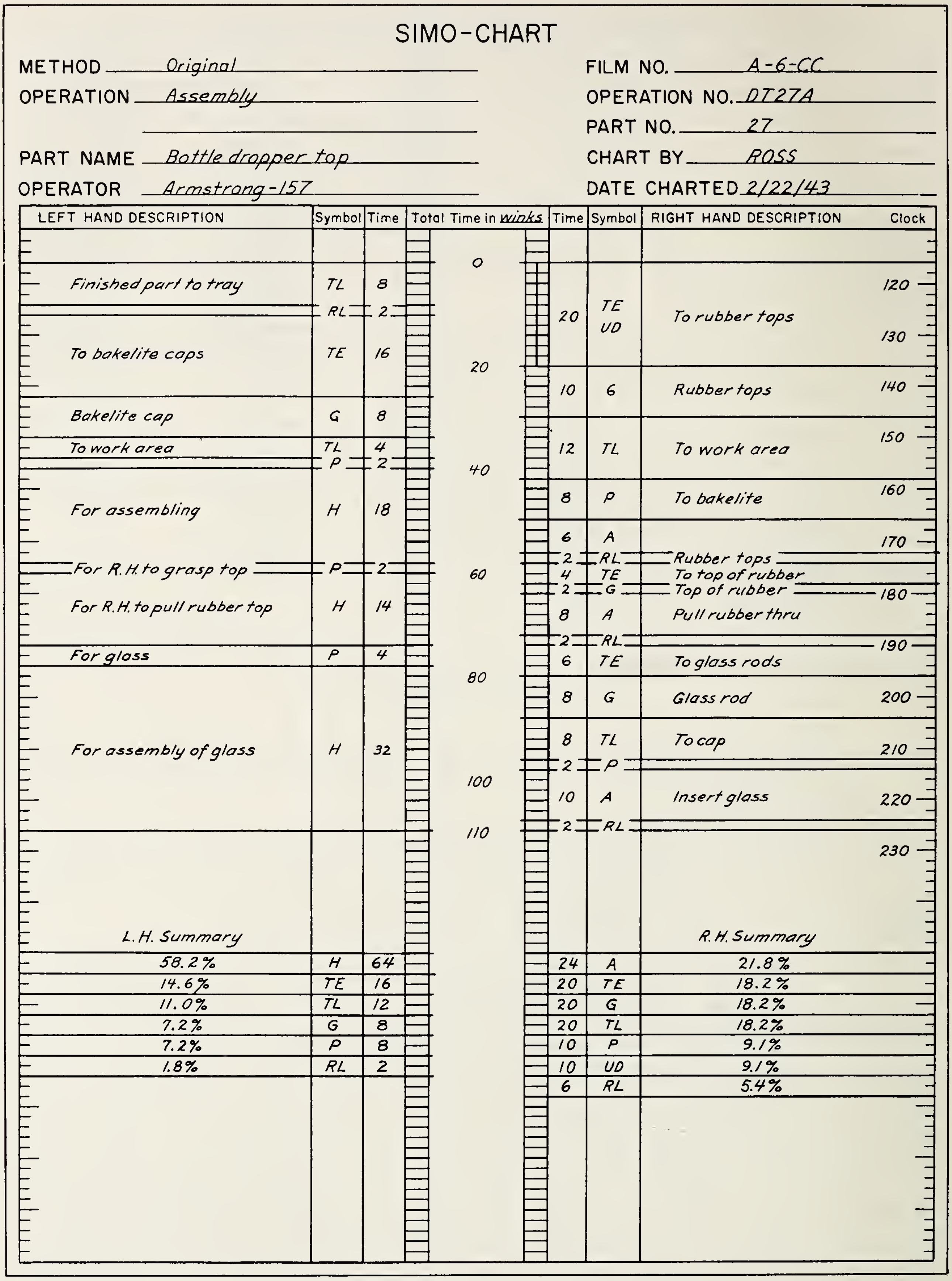
Whatever the approach, the charts and diagrams used in methods work may reveal—among other shortcomings—an illogical arrangement of tools, inefficient location of materials, idleness of men or machines, illogical phasing of left-hand motions as opposed to right-hand motions, etc. The simo-charts shown in Figs. 7-6 and 7-7 illustrate, for instance, the idleness of the hands when the operator was assembling with only one hand; the improved method indicates that both hands are used for assembly purposes in a simultaneous-motion fashion, resulting in 69% increase in output. The general aim can be summarized as follows:

1. Analysis of the motion pattern to discover any need for a change in phasing, cycling, using one hand first and the other hand next, simultaneous use of both hands, etc.
2. Inquiring into the workplace arrangement, the tools used, and the position of the materials at and around the workplace
3. Analyzing the sequence of suboperations, questioning the necessity of each step, checking the overall flow of movements, etc.
4. Analyzing the nature of motions or activities involved in the job, such as idleness, avoidable or unavoidable delays, avoidable holding of materials or tools with the hands when holding devices or clamps or the feet could be used for the purpose
5. Checking into the matter of synchronization of one operator with other, related operators; of an operator with his machines—if several machines are involved; and of men and machinery in both output and time sequence
6. Analyzing the nature of raw materials to see whether they could be changed and the operation or operations could thereby be facilitated

TIME STUDY AND METHODS STANDARDIZATION

It has already been stated that before time studies are warranted, the methods must be standardized. Without methods standardization, time standardization would lack validity in the sense that the employee using a somewhat different method than the one used during the original time study would not be able to accomplish the work in the allowed time. Just as by altering the style of swimming from backstroke to breaststroke or from butterfly to crawl will change the swimming speed, so workmen can perform faster or slower depending on the method they employ. Apparently, production will be orderly if and when the processes and the operations are standardized; and when schedules are carried out, they must be based on the standard operation time. This implies that the time study must also be based on the standard method, because otherwise neither the production planning work nor the time standard and subsequent performance control can be very useful.

Looking again at the intermittent job shop, we must emphasize that few job shops can afford to standardize their methods with a high degree of care.

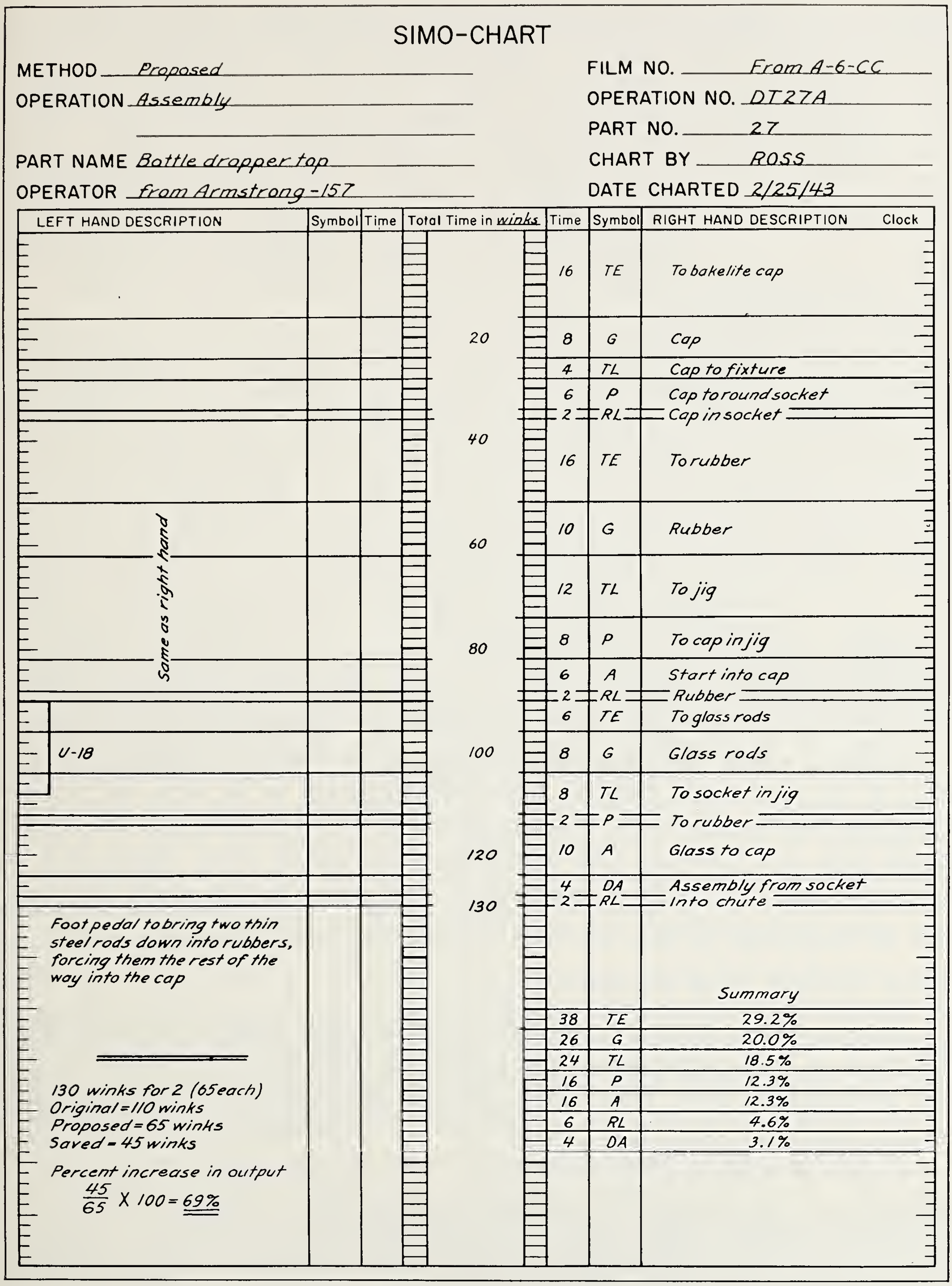


SIMO-CHART

METHOD Original
OPERATION Assembly
PART NAME Bottle dropper top
OPERATOR Armstrong-157
FILM NO. A-6-CC
OPERATION NO. DT27A
PART NO. 27
CHART BY ROSS
DATE CHARTED 2/22/43

LEFT HAND DESCRIPTION	Symbol	Time	Total Time in winks	Time	Symbol	RIGHT HAND DESCRIPTION	Clock
			0				
Finished part to tray	TL	8		20	TE UD	To rubber tops	120
	RL	2					130
To bakelite caps	TE	16	20				
				10	6	Rubber tops	140
Bakelite cap	G	8		12	TL	To work area	150
To work area	TL	4					
	P	2	40				
For assembling	H	18		8	P	To bakelite	160
				6	A		170
				2	RL	Rubber tops	
For R.H. to grasp top	P	2	60	4	TE	To top of rubber	
				2	G	Top of rubber	180
For R.H. to pull rubber top	H	14		8	A	Pull rubber thru	
				2	RL		190
For glass	P	4		6	TE	To glass rods	
			80	8	G	Glass rod	200
For assembly of glass	H	32		8	TL	To cap	210
				2	P		
			100	10	A	Insert glass	220
			110	2	RL		
							230
L.H. Summary						R.H. Summary	
58.2%	H	64		24	A	21.8%	
14.6%	TE	16		20	TE	18.2%	
11.0%	TL	12		20	G	18.2%	
7.2%	G	8		20	TL	18.2%	
7.2%	P	8		10	P	9.1%	
1.8%	RL	2		10	UD	9.1%	
				6	RL	5.4%	

FIG. 7-6. Simo-chart on the present method of assembling a bottle dropper top. (Courtesy of Marvin E. Mundel, *Motion and Time Study,* 3d ed., Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1960. Reprinted by permission of the publisher.)



SIMO-CHART

METHOD Proposed
OPERATION Assembly
PART NAME Bottle dropper top
OPERATOR from Armstrong-157
FILM NO. From A-6-CC
OPERATION NO. DT27A
PART NO. 27
CHART BY ROSS
DATE CHARTED 2/25/43

LEFT HAND DESCRIPTION	Symbol	Time	Total Time in *winks*	Time	Symbol	RIGHT HAND DESCRIPTION	Clock
Same as right hand				16	TE	To bakelite cap	
			20	8	G	Cap	
				4	TL	Cap to fixture	
				6	P	Cap to round socket	
				2	RL	Cap in socket	
			40	16	TE	To rubber	
			60	10	G	Rubber	
				12	TL	To jig	
			80	8	P	To cap in jig	
				6	A	Start into cap	
				2	RL	Rubber	
U-18				6	TE	To glass rods	
			100	8	G	Glass rods	
				8	TL	To socket in jig	
				2	P	To rubber	
			120	10	A	Glass to cap	
				4	DA	Assembly from socket	
			130	2	RL	Into chute	
Foot pedal to bring two thin steel rods down into rubbers, forcing them the rest of the way into the cap							

Summary

38	TE	29.2%
26	G	20.0%
24	TL	18.5%
16	P	12.3%
16	A	12.3%
6	RL	4.6%
4	DA	3.1%

130 winks for 2 (65 each)
Original = 110 winks
Proposed = 65 winks
Saved = 45 winks

Percent increase in output

$\frac{45}{65} \times 100 = \underline{\underline{69\%}}$

FIG. 7-7. Simo-chart depicting an improved method. Compare the original method (Fig. 7-6) with this one. (Courtesy of Marvin E. Mundel, *Motion and Time Study*, 3d ed., Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1960. Reprinted by permission of the publisher.)

However, the work may be repetitive in the sense that all jobs obtained by the plant resemble one another to some extent. Obviously, the plant will have a certain type of equipment at its disposal, and it will consequently seek work that will keep those machines busy. Because the same machines are used, the operations which they perform will be pretty similar to one another. Thus, methods standardization will increase the value of the work measurement for the eventual use of the same data in the determination of elemental time values which can be resynthesized into a time standard for various jobs. With this possibility in mind, it may pay even in job shops to indulge in methods standardization.

Methods standardization will also help the time study man in the actual timing of the job because employees then cannot sneak into the method all sorts of added motions without his readily noticing it. Generally speaking, employees have no compunction about deceiving the time study man, particularly when their pay is tied to output. It is also essential to record the speed at which the machine should run and to check the speed before starting the study, because by running the machine by a lower than required speed the time required to perform the job will also take more time than it should. The same thing applies to the tools used. A worker may pick up a hand screwdriver instead of using the prescribed screw gun, with the result that the time standard established will be so loose that it will have little validity from the point of view of production planning, performance, and cost control.

Thus, to counterbalance these tendencies, it is wise to describe on the back of the time study sheet the tools and equipment to be used, the rate of speed the machine should be run, the sketch of the workplace, and the layout of the tools and materials with which the work will be done. Again, if it is financially not worthwhile to make such a fuss about motion study, less care may cause correspondingly less accuracy in the time standard.

TIME STUDY FOR PRODUCTION

Motion standardization (methods standardization) tends to prevent undue variations in work performance and ensure the universality of standard times and performance data. Thus, those jobs not subjected to a careful enough motion (methods) analysis may not be carried out as efficiently as is desirable.

From the point of view of production, it is apparent that the accuracy of standards is of considerable importance. Inaccurate standards lead to inaccurate production plans and a corresponding lack of efficiency. Furthermore, output quotas and wage incentives based on loose or tight standards will manifest themselves in difficulty in meeting production schedules.

From the preceding discussion it seems apparent that accurate production scheduling is nearly impossible if time standards are not available. Thus, standards must be known before the start of production. One ought not think that the time standard is used only in production scheduling, even though at this point emphasis has been placed on that particular use. More will be said elsewhere about the other uses for time study. With regard to scheduling, unless one knows in advance the length of time needed to perform a given operation, it is impossible to plan with certainty the utilization of equipment. Lacking such essential information, it becomes difficult to make delivery promises and even more difficult to fulfill those promises. On the other hand, if management relies on guesses instead of on scientifically determined data, production efficiency is bound to suffer.

It should not be forgotten that time study data are only ingredients in planning an orderly flow of production. Thus, it is equally important to know when equipment is free and when it is busy with given jobs and orders. That information, together with time study data, can give management a good base for planning (scheduling) operations and keeping track of them as they progress toward completion. Furthermore, if a machine breaks down and alternative methods must be utilized, time study data are needed to predict the delay in sending the product through the alternate route. Without this kind of information, the customer cannot be assured of a definite date, in lieu of the original commitment, when the order will be delivered.

Time standards can be used in many related areas in the industrial management field, and the way in which time study data are used will depend on the particular need. For example, the way in which time study is used in determining incentive wage rates will differ somewhat from the way it is used in plant layout work, scheduling, or determining work loads. In balancing production lines and in effecting process improvements, the function of time study is to show the relative time required for given motions or operations in relationship to several factors such as left and right hand, machine time and hand time, and balance between operations in time sense. Unless the time study is available, the sequencing times and the rate of movement of the conveyor system cannot be determined. Operations along the production line must be so carefully arranged that each work station has an equal amount of work. All in all, time study plays an important part in methods planning and in every area of production planning where time requirements are prerequisites to the development of these plans.

WORK MEASUREMENT

By now it must be apparent that the function of time study is to establish information as to time requirements in the general sense and time standards, either in the form of performance standards or standard operating times, in the specific sense. The standard time will merely state the length of time needed to perform a given job under well-defined working conditions and pace. The performance standard, when used in connection with wage incentive systems, will state how many pieces an employee must deliver per hour in order to begin earning his bonus. In other words, time study establishes the time it takes to do a given job, and this may serve as a guide in production planning, plant layout, operation synchronization, and many other functions already described.

The time study will, for instance, indicate the time it takes to drill five holes of specific depth and diameter in a steel, brass, or aluminum plate; to place a pin connector into an electrical subassembly; or to solder given connections in a TV set. With this knowledge, scheduling and performance controls are facilitated. In connection with the latter, one should only mention that, based on the standard time requirement, the hourly output quota can easily be expressed: one simply divides 60 minutes by the standard time to get the output per hour that corresponds to the standard time.

As already pointed out, the time standard is used for different purposes, and, depending on the nature of the use, it may yield somewhat different results. Generally speaking, however, the standard time implies the time required to perform the operation in question by a normal, qualified worker—not a beginner on the job—working at normal pace and under the normal work environment with the normally available tools at his disposal. Obviously, the same assembly job would take differing times depending on whether a screw gun or a simple screwdriver were used. It is often misunderstood that the standard time is based on normal, not on superior, performance—at least, that is how it should be. Allowance is usually made for normal delays inherent in the job and for certain personal needs requiring the employee to leave his workplace for a short period of time or stop working for a few minutes to talk to his supervisor. As a rule, the superior worker will be able to exceed the normal output requirements.

Two Different Uses of Time Standards

At this point, mention should be made of the use that the scheduling department makes of time standards and the use that the wage and salary administrator makes of them. The standard is the same, of course, but how it is used is different. In other words, we have the same yardstick in either case, but we use the yardstick for different purposes.

Only psychology can explain why, but workers earning hourly wage rates tend to perform below the standard indicated by the stopwatch time study. It is often argued that if this happens, the standard must be wrong; but nothing could be further from the truth. The standard may be "perfect," yet employees on hourly rate will still turn out fewer pieces than the standard. This is particularly true in intermittent operations where no conveyor system or other mechanical means sets the pace. Obviously, if performance does not conform to the output rate determined by time study, scheduling of operations may be almost useless. The perfect production schedule may be completely purposeless if it is impossible to put it into practice.

Nevertheless, time study data used for scheduling must be as close to perfection as possible. The problem, then, is how to make certain that 100% theoretical performance is attained. There are usually two ways to do so: 1) have some sort of a conveyor system regulate employee performance (this is feasible in most instances only in large-scale production) or 2) use some sort of an incentive wage payment to motivate employees. One characteristic of such an incentive wage system is that bonus payments begin below expected performance. If 100% of theoretical performance, as determined by time study, were taken as the basis of incentive pay, most normal workers could not exceed the base quota which we will refer to as the performance standard. For this reason, the performance standard is so set that bonus earnings begin below the theoretical 100% of performance. Thus, an employee who earns 25 to 30% more than his normal day rate, will have exceeded the performance standard by a corresponding number of units. For psychological reasons, employees are not generally told, though the labor contract may explicitly state, that normal workers will be able to exceed the performance standard by a predetermined percentage. Hence, employees work under the delusion that they earn more because they are "of superior" talent. Even though the performance standard calls for 70 pieces per hour based on bonus considerations, management still expects 100 pieces. Thus, the workers would earn a bonus as soon as they exceeded the performance standard of 70 pieces per hour. It is considered normal that men on incentive pay earn 25 to 35% in excess of those who work on day rate.

According to the preceding explanation, time study was put to use in two different ways: 1) the scheduling department used it to schedule work expecting, say, 100 pieces per hour (100% of the time standard) and 2) the wage administrator used it to establish an incentive wage system, probably negotiated between labor and management and written into the labor contract, under which a worker receives bonus payments if he produces more than 70 pieces per hour.

There is a considerable amount of disagreement on what is the so-called normal or 100% performance. Theoretically, if the performance standard permits a normal, qualified worker to earn, say 25% more than the base rate, it is reasonable to assume that he turned out a correspondingly greater amount than the performance standard. Thus, the performance standard is bound to have been set "below" the 100% theoretical normal performance. Otherwise, no one would be able to earn a bonus—except probably the really superior worker. This author tends to agree with the Continental European concept which expects 100% of every worker. Of course, workers are pretty much the same everywhere and they tend to produce less than this 100%. Thus, if we set the performance standard requirements (for wage calculation purposes only) at, say, 75% of the time study standard, the worker begins to earn incentive wage payments when his output exceeds the performance standard.

Some experts would argue against having a double standard—one used to pay bonuses and the other to set production schedules.[2] However, psychologically it may be very important to do so. If we were to ask employees to turn out 100%, the chances are they would not do so. Therefore, we knowingly build into the standard an incentive allowance. If we want the normally attainable 60 pieces per hour (as revealed by time study), we may set the quota requirement at 51 pieces per hour. Since the worker will be able to earn his bonus as soon as he exceeds 51 pieces, he will presumably attempt to produce as much as he can to increase his bonus earnings. The superior worker will be able to produce more than 60 pieces per hour. Since, however, normal, qualified workers will be able to turn out 60, the production schedule is based on 100% performance. Incentive wage systems will be discussed more fully later in this chapter.

METHODS OF TIME STUDY

Time study men develop standards either from 1) previous performance records or 2) freshly collected data. The latter can be collected by the use of a) the decimal-calibrated stop watch, b) the constant-speed motion-picture camera, and c) time study machine (a device in which a finger-activated marker on a moving tape shows the time required to perform a given motion). Standards based on freshly developed data are referred to as "direct time study procedures." "Derivative time study," in turn, may be based on previous performance data. The latter may be collected either from production records (historical standards) or from previously made direct time studies. Historical data are not much more than the assumption that past performances are a reliable basis of future performance expectations. Therefore, scheduling is based on estimates which are supported by historical data. The time standards established on new jobs on the basis of previous time studies—that is, assuming a similarity between motions and motion time requirements—are derivative, or synthetic, time standards. If records on past performances are carefully kept and tabulated, they can be very useful in *predetermining* performance times with a considerable degree of accuracy.

Derivative time study, of course, requires the availability of previous time standards. However, to be useful, these records must be broken down into elements of jobs. That it takes 20 minutes to perform a given job means little unless elements of the job are also known—for example, that the actual drilling of 20 holes took 15 minutes, oiling took 2 minutes, and reaching for the material took 1½ minutes in the same manner that depositing the finished item took 1½ minutes. By knowing this, a plate in which 10 holes of identical size and depth must be drilled will need approximately 7½ minutes drilling time, 1 minute oiling time, and 3 minutes handling time. Thus, 7½ + 1 + 3 = 11½ minutes. More will be said about this later, but at this point it should be understood that derivative time studies have tremendous potential in industrial application and, in particular, in production scheduling of orders that are new but are similar to orders already handled by the company.

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[2] Experts in the time study field often disagree on the most reasonable basis for incentive pay and the standard. The prominent Phil Carroll, for instance, is of the opinion that a double standard is unthinkable. He wrote in a personal letter: ". . . we should get a fair day's work for a fair day's pay. That means to me, fair work standards based on sound time study. These are not softened by any bugger-factors. This fair day's work we ought to get regardless of incentives. Then, normal qualified people, not average, should make at least 20%, preferably 25-35%, on incentive. If these ideas are correct, then there is no difference between piece rates and time standards. To my way of thinking, we should talk 'measurement.' From that premise, we are concerned with a constant yardstick. . . . Hence, in either work measurement or wage incentive, we should avoid paying a second time in work standards for skill and effort already paid for in the base rate."

NATURE OF DIRECT TIME STUDY

Direct time study is based on direct observation with one of the previously mentioned timepieces. The time study begins with breaking up the job in question into its motion elements, not as finely broken down, of course, as the simo-chart in Fig. 7-7 indicates, but into such motion elements as may be useful for synthetic time study purposes also. In other words, the time study expert starts his stopwatch when the operator starts doing the job. He is not satisfied with knowing how long it takes to finish the *job as a whole,* but he wants to know how long certain separable segments of the job take. Thus, the work cycle of drilling five holes in a plate might be divided into the following motion elements:

1. Reach for the workpiece (plate)
2. Carry plate to machine
3. Place it into machine
4. Drill five holes
5. Clean machine of chips
6. Take workpiece out
7. Carry plate to bench and deposit
8. Return to machine

And from here on the next work cycle begins. Each element is timed separately. When the times required to reach, carry, place, drill, etc. are added up, the total time is the one which is necessary for performing the job cycle as a whole.

If the purpose of the time study is to gain a high degree of accuracy—and simultaneously to motion-study the job—it is possible to use a filming device and make a micromotion study. In that case, even smaller motion elements can be measured. Element 1 above would be divided into a) transport hand empty (TE), b) grasp workpiece (G), c) transport hand loaded (TL), and d) release load (RL). The time element may be read off the frame counter (*x* number of frames per minute) or from a clock which may be filmed along with the operator. Thus, at the end of the study, the time required to perform the job can be added up in the manner previously mentioned. Of course, here we speak of time elements considerably smaller than a second, which would, of course, be almost impossible to measure accurately with a hand-activated stopwatch. Here, micromotion study can be used for determining time standards for universal applicability. H. B. Maynard and Company Inc., a Pittsburgh consulting house, has used for years such a time study system. The various motion elements of any job can be found in tables, and by accumulating all motion elements which a given job contains, the performance time can be predetermined. This system, known as MTM (methods-time measurement), is illustrated in Fig. 7-8. By using the MTM system, there is no need for direct time studies (direct stopwatch measurements). However, a direct time study might be more accurate as far as specific jobs are concerned, for it is easy to overlook the appearance in a job of a motion which may lead to significant errors in the determination of the time standard.

Ordinarily, the direct time study will reveal the time for a given motion such as reaching for a workpiece or drilling five holes. Once such elemental time values are available from previously made time studies on similar jobs, it is possible to arrive at new time standards without fresh time studies.

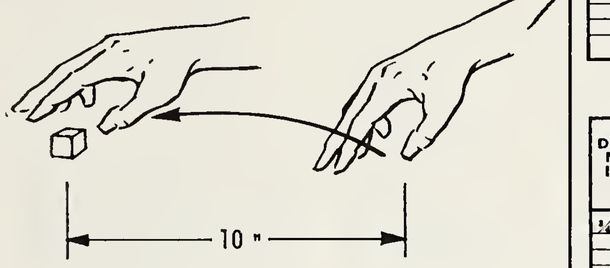
Because one can make excellent use of previous time studies on jobs which are already closed out, time study data in job shops should never be discarded. If the time standard as a whole is not applicable to a new job, some segments of direct time study may be very useful. As said before, many jobs are quite similar to one another, and because of this similarity a use and reuse of the results of previous time standards or elements of them are quite possible.

There is also a practical reason for reusing old time study data even if new direct time studies are made. Since drilling a hole of the same depth and diameter into the same type of steel plate should take the same amount of time no matter when the job is done, the time study expert may compare present performance with previous performances and, when it checks out, can cut the time study short. In other words, the time study expert may not need as many samples, that is, may not need to study one job as many times, as he otherwise would. The time study expert may study a job from 10 to 20 times over and over again, and often a much longer study is needed. In the intermittent job shop, predetermined time study systems may be of special importance because the production runs are usually so short that any system which permits a shortcut in time study is welcome. And this is one way of taking a shortcut without sacrificing accuracy.

Another good reason for the reuse of old time study data is the previously discussed difficulty with employees who may slow down while being time studied. Although they could easily "stretch" a whole job, it is very difficult to control the various elements of the job. If prior to a direct time study

1 TMU = .0000 hr
= .0006 minute
= .036 second

EXAMPLE OF USE OF TABLE



A REACH in which the hand moves to a fixed object 10 in from orignal position. Table gives a time in TMU of 8.7.

TABLE I—REACH—R

Distance Moved Inches	Time TMU A	Time TMU B	Time TMU C or D	Time TMU E	Hand In Motion A	Hand In Motion B
¾ or less	2.0	2.0	2.0	2.0	1.6	1.6
1	2.5	2.5	3.6	2.4	2.3	2.3
2	4.0	4.0	6.9	3.8	3.5	2.9
3	6.3	6.3	7.3	5.3	4.5	3.6
4	6.1	6.4	8.4	6.8	4.9	4.3
5	6.5	7.8	9.4	7.4	5.3	6.0
6	7.0	8.6	10.1	8.0	5.7	5.7
7	7.4	9.3	10.8	8.7	6.1	6.5
8	7.9	10.1	11.5	9.3	6.5	7.2
9	8.3	10.8	12.2	9.9	6.9	7.9
10	8.7	11.5	12.9	10.5	7.3	8.6
12	9.6	12.9	14.2	11.8	8.1	10.1
14	10.5	14.4	15.6	13.0	8.9	11.5
16	11.4	15.8	17.0	14.2	9.7	12.9
18	12.3	17.2	18.4	15.5	10.5	14.4
20	13.1	18.6	19.8	16.7	11.3	15.8
22	14.0	20.1	21.2	18.0	12.1	17.3
24	14.9	21.5	22.5	19.2	12.9	18.8
26	15.8	22.9	23.9	20.4	13.7	20.2
28	16.7	24.4	25.3	21.7	14.5	21.7
30	17.5	25.8	26.7	22.9	15.3	23.2

CASE AND DESCRIPTION

- A Reach to object in fixed location, or to object in other hand or on which other hand rests.
- B Reach to single object in location which may vary slightly from cycle to cycle.
- C Reach to object jumbled with other objects in a group so that search and select occur.
- D Reach to a very small object or where accurate grasp is required.
- E Reach to indefinite location to get hand in position for body balance or next motion or out of way.

TABLE II—MOVE—M

Distance Moved Inches	Time TMU A	Time TMU B	Time TMU C	Hand in Motion B
¾ or less	2.0	2.0	2.0	1.7
1	2.5	2.9	3.4	2.3
2	3.6	4.6	5.2	2.9
3	4.9	5.7	6.7	3.6
4	6.1	6.9	8.0	4.3
5	7.3	8.0	9.2	5.0
6	8.1	8.9	10.3	5.7
7	8.9	9.7	11.1	6.5
8	9.7	10.6	11.8	7.2
9	10.5	11.5	12.7	7.9
10	11.3	12.2	13.5	8.6
12	12.9	13.4	15.2	10.0
14	14.4	14.6	16.9	11.4
16	16.0	15.8	18.7	12.8
18	17.6	17.0	20.4	14.2
20	19.2	18.2	22.1	15.6
22	20.8	19.4	23.8	17.0
24	22.4	20.6	25.5	18.4
26	24.0	21.8	27.3	19.8
28	25.5	23.1	29.0	21.2
30	27.1	24.3	30.7	22.7

Wt. Allowance Wt. (lb.) Up to	Wt. Allowance Factor	Wt. Allowance Constant TMU
2.5	1.00	0
7.5	1.06	2.2
12.5	1.11	3.9
17.5	1.17	5.6
22.5	1.22	7.4
27.5	1.28	9.1
32.5	1.33	10.8
37.5	1.39	12.5
42.5	1.44	14.3
47.5	1.50	16.0

CASE AND DESCRIPTION

- A Move object to other hand or against stop.
- B Move object to approximate or indefinite location.
- C Move object to exact location.

TABLE III—TURN AND APPLY PRESSURE—T AND AP

Weight	30°	45°	60°	75°	90°	105°	120°	135°	150°	165°	180°
	Time TMU for Degrees Turned										
Small— 0 to 2 Pounds	2.8	3.5	4.1	4.8	5.4	6.1	6.8	7.4	8.1	8.7	9.4
Medium—2.1 to 10 Pounds	4.4	5.5	6.5	7.5	8.5	9.6	10.6	11.6	12.7	13.7	14.8
Large— 10.1 to 35 Pounds	8.4	10.5	12.3	14.4	16.2	18.3	20.4	22.2	24.3	26.1	28.2

APPLY PRESSURE CASE 1—16.2 TMU. APPLY PRESSURE CASE 2—10.6 TMU

TABLE IV—GRASP—G

Case	Time TMU	DESCRIPTION
1A	2.0	**Pick Up Grasp**—Small, medium or large object by itself, easily grasped.
1B	3.5	Very small object or object lying close against a flat surface.
1C1	7.3	Interference with grasp on bottom and one side of nearly cylindrical object. Diameter larger than ½".
1C2	8.7	Interference with grasp on bottom and one side of nearly cylindrical object. Diameter ¼" to ½".
1C3	10.8	Interference with grasp on bottom and one side of nearly cylindrical object. Diameter less than ¼".
2	5.6	**Regrasp.**
3	5.6	**Transfer Grasp.**
4A	7.3	Object jumbled with other objects so search and select occur. Larger than 1" x 1" x 1".
4B	9.1	Object jumbled with other objects so search and select occur. ¼" x ¼" x ⅛" to 1" x 1" x 1".
4C	12.9	Object jumbled with other objects so search and select occur. Smaller than ¼" x ¼" x ⅛".
6	0	Contact, sliding or hook grasp.

TABLE V—POSITION*—P

CLASS OF FIT		Symmetry	Easy To Handle	Difficult To Handle
1—Loose	No pressure required	S	5.6	11.2
		SS	9.1	14.7
		NS	10.4	16.0
2—Close	Light pressure required	S	16.2	21.8
		SS	19.7	25.3
		NS	21.0	26.6
3—Exact	Heavy pressure required.	S	43.0	48.6
		SS	46.5	52.1
		NS	47.8	53.4

*Distance moved to engage—1" or less.

TABLE VI—RELEASE—RL

Case	Time TMU	DESCRIPTION
1	2.0	Normal release performed by opening fingers as independent motion.
2	0	Contact Release.

TABLE VII—DISENGAGE—D

CLASS OF FIT	Easy to Handle	Difficult to Handle
1—Loose—Very slight effort, blends with subsequent move.	4.0	5.7
2—Close — Normal effort, slight recoil.	7.5	11.8
3—Tight — Considerable effort, hand recoils markedly.	22.9	34.7

TABLE VIII—EYE TRAVEL TIME AND EYE FOCUS—ET AND EF

Eye Travel Time $= 15.2 \times \frac{T}{D}$ TMU, with a maximum value of 20 TMU.

where T = the distance between points from and to which the eye travels.
D = the perpendicular distance from the eye to the line of travel T.

Eye Focus Time = 7.3 TMU.

FIG. 7-8. Methods-time measurement application data. (Courtesy of MTM Association for Standards and Research and H. B. Maynard and Co.)

the time study man knows the time values of motion elements and the drilling of 10 holes (which he knows from a previous time study should need approximately 7½ minutes) takes 20 minutes, he might be rather suspicious that something is wrong with the performance; either the drill is dull, the steel is too hard, or the employee is stretching the job. Thus, the knowledge of elements of previous time studies may not only accelerate the time study procedure but also reveal shortcomings or pitfalls of measurement and lead to a more accurate time study in a shorter period of time.

Generally speaking, the study of 10 to 15 work cycles will give a standard of considerable accuracy. To get greater accuracy, the observation must be lengthened to 20, 25, or even more cycles. There are tables and formulas which are capable of predicting the number of samples needed to obtain the desired accuracy of the time standard.[3] These take the statistical probability of sampling errors into consideration and state how many readings are necessary to fall within a given range of error.

DIRECT TIME STUDY PROCEDURE

The general procedure in time study (work measurement) is as follows:

1. Observation (standing behind or near a worker and collecting time values as the job is being done)
2. Rating the performance, that is, reducing the performance of a slow or fast performer to "normal" time needs (base time)
3. Determining allowances (personal needs, regular and irregular occurrences)
4. After averaging the observed time values, prorating these values, and adding items 2 and 3 together, one gets the time standard.

The following must be remembered so far as point 2 is concerned. If the observation time values on a specific motion element averaged out at 0.50 minutes but the employee worked at 50% efficiency, the *base time* is 0.25 in lieu of 0.50 (decimal minutes). If an arbitrary allowance factor of 10% is taken, the time standard for a given job (or element thereof) is:

	0.25	base time, reduced from 0.50
	+0.025	10% allowance
Standard time	0.275	decimal minutes

PREDETERMINED TIME STUDY PROCEDURE

The synthetic method of time study may be based on the availability of MTM data shown in Fig. 7-8 or on time study data from previous, similar jobs. The latter are easier to calculate and tend to be more accurate, since job similarity tends to confirm the equality of time requirements when the motion pattern is similar. In other words, the chances are that the variances between two different jobs may not be too great. Elements identical on two or more jobs are picked out as needed and resynthesized to give a time standard on a new job.

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[3] See page 277.

In summary then, when process sheets on a new order are developed, they are turned over to three different departments, namely: 1) methods engineering, 2) time study, and 3) production control. If the size of the production run does not warrant careful motion analysis, the methods department ignores the process sheet. If careful study is warranted, improvement on the method is attempted and is subsequently followed up by time study. The new process sheet finally goes to production control. Time standards on the various operations are sent to production control, where the product is routed and scheduled through the various operations. It is important to remember that the production control department could not possibly do accurate scheduling without the availability of time standards.

HISTORICAL TIME STUDY PROCEDURE

Some job shops make such a wide variety of products in such small quantities that it would be unrealistic to make direct time studies on every order they receive. Yet these jobs may still have a great deal of similarity. In view of the variety, it may be unwise to develop standard motion patterns and hold employees to it. Yet some sort of time standard is needed as a basis for developing production schedules.

In situations of this kind, historical time study may be the answer. A foundry, for instance, receives orders for different shapes of castings. Upon a careful analysis, it is very likely to be discovered that despite multiplicity of differences between orders, the production process is much the same. While the shape and form of the molds into which the metal is poured differ, the pouring operation and the rest of the production process cannot possibly vary substantially. It follows, therefore, that the time requirement will remain pretty much the same for castings of different shapes but approximately the same weight.

A careful study of production records (time cards, output data, cost records, total man-hours per output, etc.) in the case of such a plant (a foundry) will probably reveal a definite relationship between output and man-hours of labor needed in the production of castings. The company will find the time study data very useful for scheduling purposes if the tonnage of castings to be produced is known and is related to the man-hours of labor needed to produce this tonnage. This situation exists in many industrial enterprises. There is usually a common denominator by which output can be related to time requirements. A comparison of production records over the past few years may indicate the number of hours needed to complete a gallon of *x* chemical, a ton of steel, a dozen shirts, a batch of bread, and so on.

Under the assumption that neither the excellence of supervision nor the methods of production nor the expected labor efficiency will undergo substantial change, the inference can be made that production data of past periods are pretty representative of future expectations. Therefore, the average performance times of past periods are used to plan and schedule production in the future. The averages expressed by some common denominator, such as tons or gallons per man-hour of labor, are usually adequate for orderly scheduling. The example in Table 7-1 may illustrate the point. If the quarterly output of a foundry was as tabulated, the time standard per ton of steel (casting) is ½ hour (20,000÷400,000=½ hour). Although four quarters are not necessarily representative of normal performance, the information may be useful in future scheduling and cost estimating.

TABLE 7-1

Quarters	Tonnage	Yield per Man-Hour of Labor
1	100,000	4,850
2	98,000	5,050
3	99,000	5,200
4	103,000	4,900
Totals	400,000	20,000

It must be apparent that this kind of time study does not require a timepiece, but is based purely on past performance records. Although this statistical (historical) method of arriving at a production standard is far from accurate, it is a feasible means of arriving at some basis upon which production scheduling is possible.

Accuracy Requirements

The three different methods of time study—direct, historical, and synthetic—vary in accuracy. This may not matter because the three different production processes—intermittent, repetitive, and continuous—do not require the same degree of accuracy either. Obviously, if we could gain accurate time study all the time without substantial investment of time and money into time study engineering, we would always prefer a precise standard. But because the more accurate the time study is, the more costly it is to obtain, we are often satisfied with a less than perfect standard that fits in with our production requirements.

Continuous production needs time study when the production line is built and the production flow and the balance between work stations is established. Since the flow is controlled mechanically and the mechanical device, such as a conveyor, moves at a predetermined rate of speed, it stands to reason that the accuracy of time study must be so high as to aim at perfection. If this situation is compared with that in the job shop, it will be seen that there the need for accuracy is less important since the production flow is an artificial one. In the job shop, one schedules operations to departments and to different machines. Without time study, scheduling would not be possible, but it is certainly not necessary to have the operation time reduced to split seconds of accuracy. If one errs plus or minus 5 or 10%, scheduling is still fairly accurate and the overall flow of production can still be maintained.

Since time study is hardly a science, although at least it is a scientific procedure, it is evident that mathematical precision is not possible. It is important, too, to remember that behind every machine a human being stands, and the individual's performance depends not only on his skill, diligence, stamina, physical endurance, and many other factors but also on his frame of mind. Thus, it is difficult to establish standards of universal validity. Nevertheless, by taking more and more samples and by spending more and more time on studying the job in question, it is possible to achieve an accuracy directly proportional to the number of samples taken. Mathematically,[4] to be 95 of 100 times correct within ±5% (that is, 5% of $\overline{X}$ equal to $2\sigma\overline{X}$), we get

$$0.05\overline{X}=\frac{\Sigma X}{20N}=2\frac{\frac{1}{N}\sqrt{N\Sigma X^2-(\Sigma X)^2}}{\sqrt{N'}}$$

$$\frac{\Sigma X}{20}=\frac{2\sqrt{N\Sigma X^2-(\Sigma X)^2}}{\sqrt{N'}}$$

and

$$N'=\left(\frac{40\sqrt{N\Sigma X^2-(\Sigma X)^2}}{\Sigma X}\right)^2$$

If the accuracy requirement is set at 95/100 of being within ±10% error range, then

$$N'=\left(\frac{20\sqrt{N\Sigma X^2-(\Sigma X)^2}}{\Sigma X}\right)^2$$

The required number of readings may be predetermined and tables may be developed. The function of such a table is to give the time study man a guide to how often he should time a given job in order to attain desired accuracy.

It should be noted, however, that the method of timing with a stopwatch, aside from the number of samples the time study man takes, may also influence the accuracy. Thus, for instance, continuous timing requires that the watch be left running during the whole work cycle, whereas in the snap-back method of timing, the hand of the stopwatch is returned to zero every time the operator completes an element of the job. While the cycle time as a whole is usually correct with the continuous timing method, the elemental time values might not be so precise because they must be read while the watch hand is in motion. With the snap-back method of timing, the opposite is true. The reading of each element being measured tends to be rather accurate, but the cycle time may vary somewhat because of the small errors which occur between snapping the hand back and reading the value indicated on the stopwatch. A variety of decimal stopwatches are shown in Fig. 7-9.

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[4] The mathematics of statistical quality control in Appendix B is applicable here also. Whereas there it is indicated how many samples must be taken to err within limits in setting quality standards, here the formula indicates how many samples the time study man must take to fall within error limits. Obviously, to be accurate, the number of readings must be raised. Ten readings are needed in most instances unless synthetic standards confirm the validity of the times earlier than this.

PERFORMANCE RATING

Although most time study experts like to think that the time standard is an accurate indication of the time required to perform a given operation, it is by no means a precise and valid method by which performance can be expressed. As just indicated, the number of samples and the method of timing are important. Further distortion may result from the leveling (rating) procedure, which adjusts the time value measured from an abnormal performance to a "normal performance time." The value of time study is beyond doubt, but it must be apparent that the word "accurate" must be taken with a grain of salt. It should never be forgotten that we are attempting to measure human performances, and human beings are only "human." Perfection is something we seek but never reach.

When setting work (time) standards, it is difficult to escape judgment making on the part of the time study expert. Workers usually work differently because of their physical makeup, skills, shortcomings, diligence, and so on. Their psychological frame of mind is equally important, because a man under severe tension cannot concentrate on his job. In other words, the employee will work either faster or slower than the so-called normal performance. It is up to the time study man to determine whether the particular element which he measured was performed at greater or less than 100% of assumed normal efficiency. It is undoubtedly true that when judging this percentage, time study technicians may pick the wrong leveling factor. Yet it should be remembered that an expert cannot err so badly that the time study would turn out to be useless. This is a question on which labor unions and managements cannot reach agreement. Individual judgment cannot be avoided; and whether we like it or not, this kind of judgment is always a part of the time study procedure.

When the standard serves as the wage base, employees have a particular interest in deceiving the time study expert. The more time allowed on a job, the greater is the possibility for extra income. For obvious reasons, then,

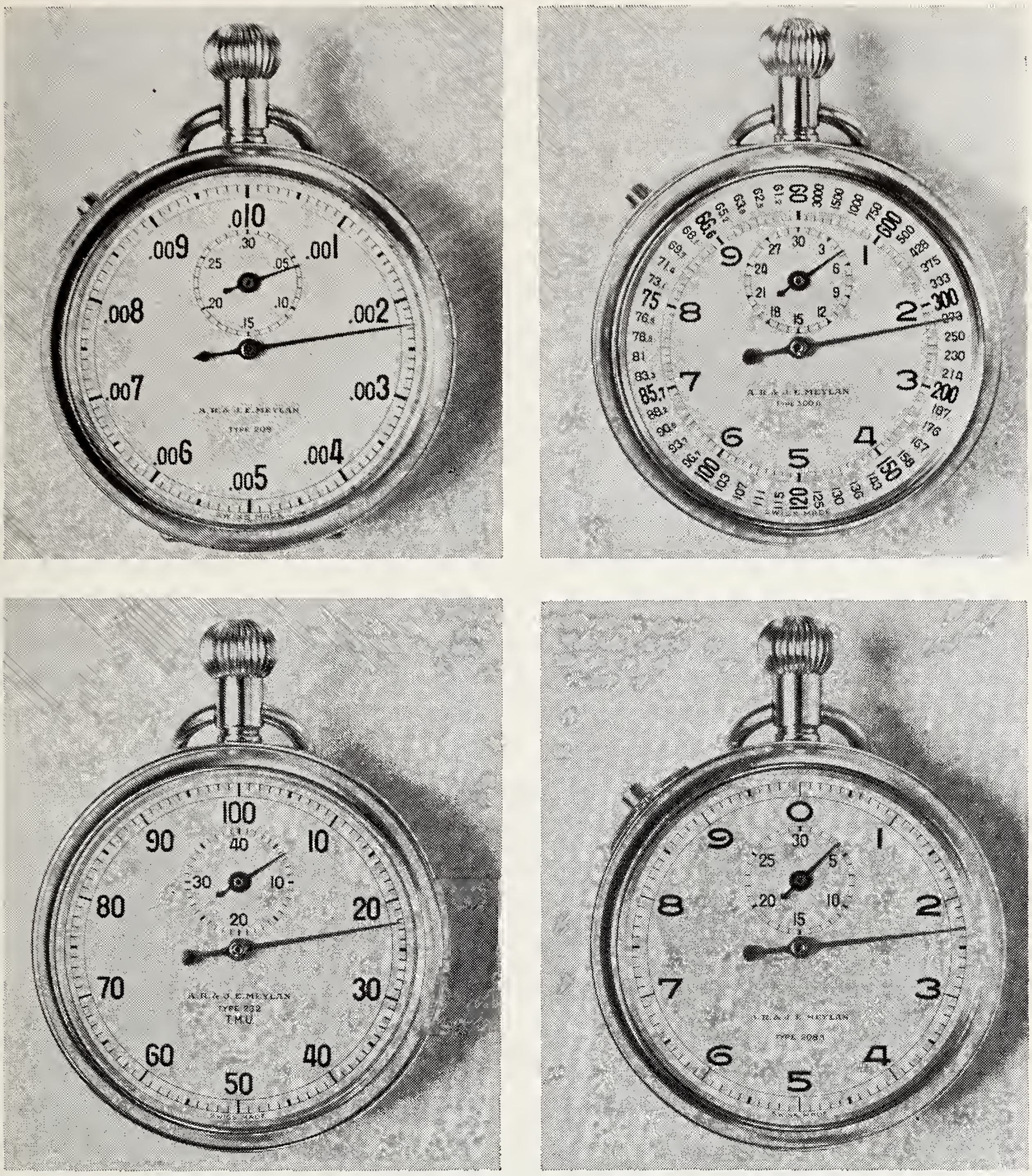


FIG. 7-9. Decimal stopwatches. (Courtesy of Meylan Stopwatch Corp.)

employees tend to slow down while being time-studied. To counterbalance this tendency, time study experts must be able to judge the extent to which slowdown takes place and express it as a percentage of normal pace.

While the rating of performance is a controversial issue in the time study field, there is no other method, apart from human judgment based on observation and experience, of measuring the tempo with which the employee performs on the job. Speed can, however, be easily recognized in the same way that the highway patrol recognizes speeding cars without the use of a radar speed check. An experienced man can tell the percentage of the higher speed rather accurately, even though not precisely.

Selecting "average" workers to perform the jobs has been attempted, but difficulty arises in determining who is an average worker. Therefore, the rating of the work tempo remains less difficult and more accurate than the method of finding and using average workers for time study purposes.

Judgment must be exercised at some stage in deciding the normal rate. The only trouble is that each time study man may have his own interpretation of what is normal. For this reason, attempts have been made to standardize the judgment factor by developing pace-rating films on benchmark jobs. When the time study experts are trained—via the pace-rating films—to discover a "normal tempo," it becomes feasible to get a fairly uniform treatment from the various time study men assigned to time study operations in the shop. Although these films facilitate pace rating, they only standardize judgment, and do not eliminate it.

Synthetic standards are suggested as a good check on time studies developed through direct time studies. As a matter of fact, it is assumed that by taking fewer samples and comparing the time study results with preestimated time values (after these time values have been synthesized), it is possible to reach accuracy, check on the validity of the judgment involved in rating, and get a time study procedure that is cheaper overall yet better as far as accuracy and validity are concerned.

To close this section, let us illustrate the mechanics of rating. For the sake of the example, we assume that the time study observer breaks the job down into elements I, II, III, and IV. Then he measures these elements as the employee performs the job. When sufficient samples are collected, he averages the performance times. The figures in Table 7-2 are already averages (either the mean, mode, or median).

TABLE 7-2

Elements	Name of Element	Average Time, Minutes	Rating Factor, Percent
I	Walk to storage, pick up workpiece and place it in machine	0.88	50
II	Milling operation (automatic feed)	0.42	100
III	Take workpiece out	0.54	130
IV	Carry to track and deposit	0.46	50

The result of the calculation of the time standard is

$$\begin{array}{lll}
0.88 \times 0.50 & (50\%) & = 0.44 \\
0.42 \times 1.00 & (100\%) & = 0.42 \\
0.54 \times 1.30 & (130\%) & = 0.70 \\
0.92 \times 0.50 & (50\%) & = 0.46 \\
\overline{2.76} & & \overline{1.42} = \text{base time for job}
\end{array}$$

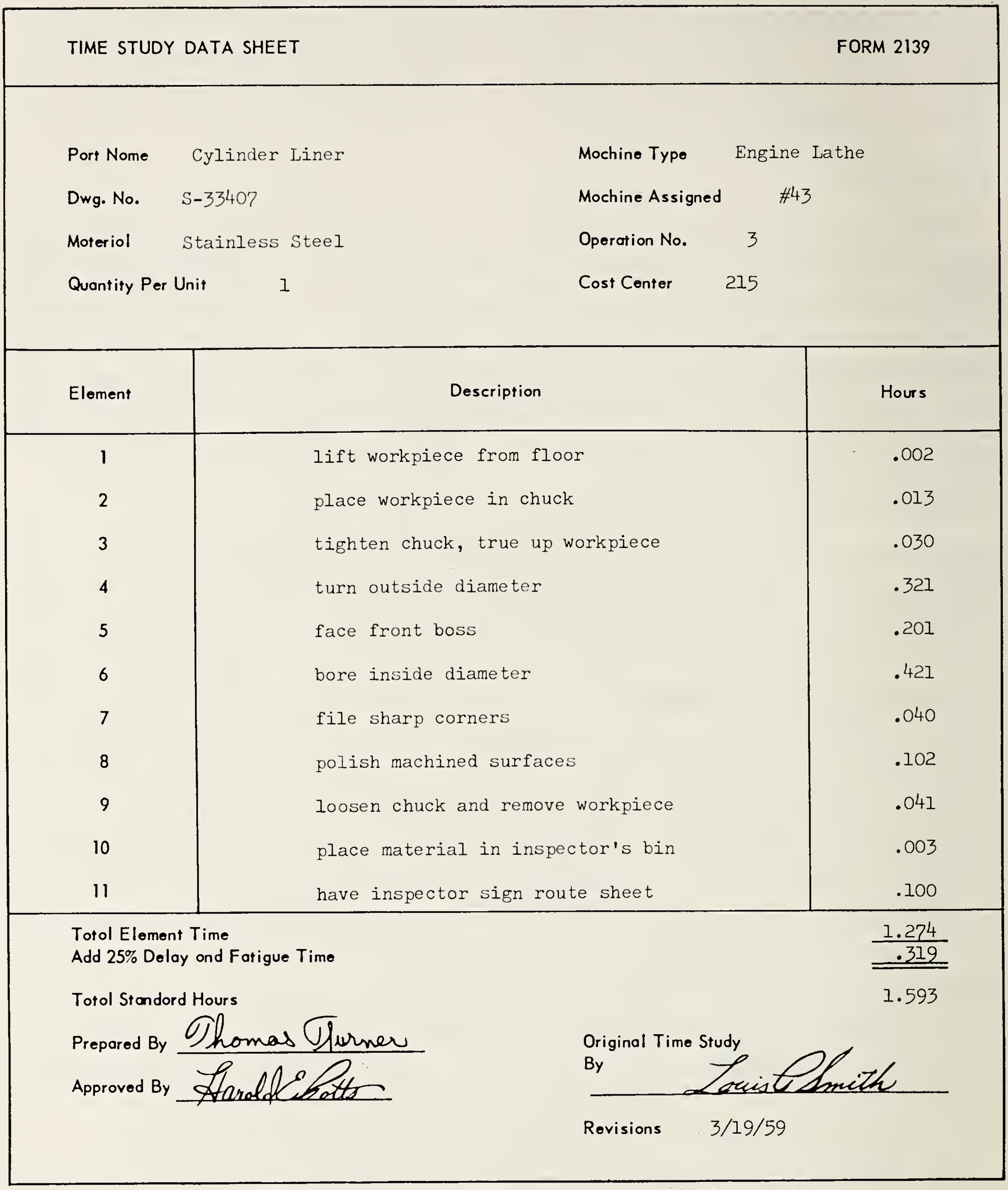
Although the worker spent on the average 2.76 decimal minutes on the job, the time study expert prorated the job to 100% efficiency. The prorated value (1.42) is the so-called base time. It is called base time because further calculations are based on it.

ALLOWANCES

When the base time is established, the allowance factors must be determined. Allowances are justified on grounds of certain personal needs, and the scheduler must take them into consideration. It is customary nowadays to permit employees a coffee or smoke break several times during the day; employees must occasionally go to the rest room, drink water, etc.; and while this is happening, they are not producing. If allowance for these necessary time losses were not given, the schedule would require more of the employees than they are able to produce.

Since we are here concerned with time study for the job shop, the contention is made that the allowance factors must be arbitrarily selected rather than collected through careful observation of motion elements which ordinarily would occur in the job or in the shop while work is being performed. An actual study of all extracurricular activities on the job might be too costly and meaningless in job shops where different orders and jobs are being worked on every day. Therefore, it is reasonable to assume a 15-minute break in the morning and in the afternoon, and that 18 minutes is adequate for drinking water, changing from work clothes into street clothes and vice versa, washing hands, cleaning the machine, etc. Since this amounts to 48 minutes, or approximately 10% of a normal work day (actually it is 11%, since by assuming a 480-minute day we give 10% allowance on the allowance factor itself), a simple addition of 10% to the base time will give the standard time. Most enterprises complicate the calculation by separate calculation of personal needs, fatigue allowances, and delay allowances. Even though accuracy is of considerable importance, in job shops an arbitrary commonsense allowance calculation is justified (see Fig. 7-10). In continuous production, and particularly in repetitive operations, such precision is more proper.

In reiterating the necessity for allowances, it should be kept in mind that we are dealing with human beings; and because human beings are human, allowances must be given for certain things which are done during working hours. No one can be expected to work like an automaton. Unless the time study considers these things, scheduling will suffer because we are assuming that employees work uninterruptedly. The unattainable standard is not good from the point of view of production control; neither is it good from the point of view of supervision. The unattainable standard undermines morale, and then the foreman has complaining and discontented employees to deal with.



TIME STUDY DATA SHEET FORM 2139

Part Name	Cylinder Liner	Machine Type	Engine Lathe
Dwg. No.	S-33407	Machine Assigned	#43
Material	Stainless Steel	Operation No.	3
Quantity Per Unit	1	Cost Center	215

Element	Description	Hours
1	lift workpiece from floor	.002
2	place workpiece in chuck	.013
3	tighten chuck, true up workpiece	.030
4	turn outside diameter	.321
5	face front boss	.201
6	bore inside diameter	.421
7	file sharp corners	.040
8	polish machined surfaces	.102
9	loosen chuck and remove workpiece	.041
10	place material in inspector's bin	.003
11	have inspector sign route sheet	.100

Total Element Time	1.274
Add 25% Delay and Fatigue Time	.319
Total Standard Hours	1.593

Prepared By Thomas Turner

Approved By Harold E. Potts

Original Time Study By Louis C. Smith

Revisions 3/19/59

FIG. 7-10

ENFORCEMENT OF OUTPUT QUOTAS[5]

The fact that careful time studies are collected and calculated does not necessarily imply that the production planning and control department can fully rely on standard operation times. Since employees resist regimentation, they might—despite precise knowledge of how many pieces can be turned out per hour—turn out less than the required quantity. It is not an exaggeration to say that production often turns out to be exactly half of what management plans. Obviously, when management is under pressure to meet production or sales requirements and it notices that the schedules are always and consistently out of balance, the first question is whether the standards are correct. As a rule, barring erroneous time study calculation, the standards will be all right, but it is still impossible to get enough work done to justify accurate scheduling on a 100% basis, that is, to expect output corresponding precisely with time standards.

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[5] Based on two articles appearing in the December, 1958 issue of *Machine and Tool Bluebook* under the title "Incentives for Production Scheduling," and in the April, 1961 issue of *Modern Machine Shop* under the title "A Wage Incentive Need Not Be a Give-Away." Both articles were written by the author of this book.

What should be done under such conditions? We know how much can be produced in an hour, but the fact is that we never get the quantity which we expect. Employees seem to work normally. Supervision seems to be adequate. There is no specific element which seems to hold up production, yet we are still behind. Should the scheduling department set realistic programs by actually scheduling half of what the time standard says we can produce? Or should we strictly enforce production standards? This is not a simple question to answer, because if we have a labor union in the shop, enforcement through disciplinary action and through other so-called slave-driving techniques becomes almost impossible. How far do we get with driving and pushing employees? The answer is, not far.

The continuous producer can eliminate this restriction of output by the introduction of a constantly moving conveyor system, but the intermittent job shop is at a loss. Each order is different, and each part has its own path in the production process. Employees have pretty much the final say on how fast an item is going to be produced, despite management's knowledge of performance times.

The main problem, of course, is always that if employees are paid straight day rate or hourly wages and output is not tied to income, the employees have no incentive to put out more work than is necessary to keep their jobs. There are some men and women who produce diligently, but they are the exception rather than the rule in an industrial society like ours. The majority of employees always perform below the performance expected by management.

Human relations experts claim that if people are treated properly, the expected standard output can be raised without difficulty, but experienced production foremen do not agree. This is not because employees want to short-change management, but because the employee concept of a fair day's work is different than the management concept. This difference is the reason why employees withhold their full productive power. The fear of "working oneself out of a job" plays a part in this output restriction process. Without doubting the value of good human relations, experience indicates that production standards cannot very well be enforced unless special wage incentives are provided.

The introduction of operation standards merely does away with the uncertainty over what can be expected of a normal employee on a given job and indicates the output capacity of given equipment or departments. Operation standards are the basic tools of production scheduling, but they do not guarantee the accomplishment of operation times. This can only be done by resorting to a wage incentive system.

REASONS FOR INCENTIVES

Incentives are essential in job shops to support the efforts of the production control departments. Production scheduling is based on the assumption that time study data are truly convertible into production units. But, as the preceding discussion indicates, setting schedules and meeting them are two different things.

Production scheduling in job shops is one of the most important factors in production efficiency. Yet, unless management is able to get work done according to schedule, lack of employee cooperation can easily nullify the value of centrally organized production control. Since it is essential that plans be consistently accomplished, wage incentives are an essential ingredient of the production control system.

Remember that the production control department calculates work loads and the availability of equipment time. By that means the company knows how much work it can expect and when it can promise delivery. If there were no production control, rush orders could not be accommodated, delivery promises could not be maintained, and overtime work at time-and-a-half would be customary. The production control department exists to eliminate all these shortcomings and the inefficiencies that go with them. The production control department, then, receives information as to what process an item should go through, and subsequently the time standards arrive from the industrial engineering department. Equipped with this information, the production control department is able to develop a production program or fit a new order into the existing production program so that the plant can deliver the finished goods according to a promised date. Yet if the mere conversion of time standards into production schedules does not work, the production control department's work is futile. A production schedule which is good only on paper is no good at all.

To make production planning effective, the incentive system must be built into the production system. It should be emphasized, however, that incentives are not necessary in those companies where a conveyor system can do what supervisors cannot. Make a man a part of a conveyorized production line and he will work as fast, provided he has the appropriate amount of time to accomplish his share of the work load, as the line moves. If the plant is a fortunate one and can do this, an incentive system would be an unnecessary headache. But where the movement of production depends largely on the employees' willingness to work as required, a wage incentive system may be able to do what a mechanized system would do: inspire people to produce up to their capabilities, which, of course, in this case means production up to standard performance in the expectation of bonus earnings.

The importance of incentives cannot be overemphasized, but no one should assume that incentives are substitutes for production scheduling. The incentive system is merely an adjunct to the production control system. Obviously, the incentive system will work if the wage payment is indeed considered by employees as "incentive." An incentive system is not properly devised if people whom the system purports to motivate to turn out a fair day's work do not consider the additional pay an adequate incentive to exert themselves.

Basically, every incentive system works through the wage payment. A certain minimum of performance is required, and if it is surpassed, the reward is extra pay. The monetary reward above the normal day rate is the incentive. Some well-engineered plants can successfully operate with 15% incentive, but the figure can go higher than that—even up to 20 or 25%. This means that an employee whose daily income would normally be $10 might end up with $11.50 or $12.50 in his pay envelope, depending on the size of the incentive. So, as a direct result of the wage incentive system, the company might pay from 15% to 25% more than under the hourly wage payment system; but this would largely depend on the incentive plan designed or adopted. Although employees receive more pay, the overall effect of a wage incentive program is orderly production and a reduction of costs. The sign of a good incentive system is that, even though more is paid out in wages, the unit cost is reduced. In other words, there is nothing wrong with paying more if the added output will offset the added cost of incentives. The only question is how much more can be expected for the outlays and how management can get that added output.

Time Study and Wage Incentives[6]

To begin with, a wage incentive system should not be installed unless reliable time standards are available on all operations. Once they are available, management knows what amount can be produced. A comparison of actual output and expected output will ordinarily reveal that employees quite often do not produce much more than half the standard. Now, if it is known that employees should produce 60 pieces per hour on a given job but are turning out only 30 pieces, the plant cannot schedule operations on the basis of the time standard, because after awhile it becomes obvious that it makes no sense to toy with unrealistic requirements. If management insists on the 60 pieces per hour requirement, organized labor may go—and it actually has often gone—on strike instead of complying with management's demand, even though the time standard represents no more or less than a good day's work. The fact is that management is often unable to get production up to the standard which time study indicates employees are capable of turning out after due regard for allowances. It is not enough to know that the production standards are fair and can be achieved; the question is *how* performance standards can be converted into actual output. The scheduling will fulfill its purpose only if time values can be directly converted to output values.

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[6] Though this presentation may differ from that of other exponents of wage incentives, the basic concepts do not.

The necessity for paying more, in the sense that the last few units will earn bonuses for the worker, has already been established. But how can one pay more, yet cut the unit costs at the same time? Relying on the preceding example of only 50% efficiency (actual output of 30 pieces in comparison with expected output of 60 pieces), let us assume that, in the considered opinion of management, employees would regard 15% extra income for a fair day's work as an adequate incentive. In other words, if an employee produced a fair day's work (100% of standard), he would earn $92, instead of the day-rate-based weekly income of $80. If this 15% extra pay would induce the workers to produce 60 pieces instead of 30, productivity increases would have more than compensated for the higher wage rate, that is, day rate plus incentive bonus.

SETTING INCENTIVES

The output capability of the average employee on the job in question is 60 units per hour; in other words, according to the time standard, 1 minute is necessary to turn out one unit of output. Since this is based on a normal man's normal performance under normal working conditions and at the normal pace, it must be apparent that only superior workers could surpass the standard. Most normal workers would produce that amount if they put in a good day's work. Now to assure that even the normal employee can earn incentive pay, it is essential to let the bonus pay begin at less than 100%, say at 85% of parity. As far as the employee is concerned, this simply means that instead of 60 pieces, he is asked to turn out 51 pieces, yet if he turns out all 60, on the last 9 pieces he earns some predetermined incentive. If there is a labor union in the plant, the exact percentage at which incentive earnings begin is a negotiated figure.

The normal man will, therefore, earn 15% of extra income if he turns out the standard time-based performance, that is 100%. The superior man may earn more than 15%, depending on his ability to turn out goods. Assuming accuracy of the time standard, very few, if any, men will greatly exceed 15% of extra income. If 15% incentive bonus is considered inadequate to "induce people to work so hard," the incentive system may still not work and 20%, 25%, or an even higher bonus must be awarded.

To meet the production schedule, time study data must be so used as to offer inducement to workers. The standard is, of course, not reduced, but for wage payment purposes, the level at which bonus payment will begin will always fall below the 100% output possibility. In other words, management is often willing to pay a bonus on the last few pieces just to assure that production schedules based on time standards are accomplished. There is obviously great value in the ability to attain preplanned objectives, even if it requires bonus payment. Apparently, what the wage administration does is of no concern to the production scheduling group. Yet, production schedules would not be accomplished had the bonus payment not begun at lower than expected output. It may seem peculiar, but management must often pay extra for something which it should get anyway.

In reading the preceding paragraphs, the student may have confused the incentive system with the piece-rate system. The confusion is not without foundation. The only difference between wage incentive systems and piece-rate systems is that the former usually guarantees the base pay and the latter does not. In other words, the piece-rate system has some penalty aspects. In the wage incentive system performance is rewarded, but lack of performance is not penalized. Of course, most employers would not keep a man on the payroll for long unless he put out what was expected of him.

The wage incentive system, or the piece-rate system, tends to assure that employees produce at the output level implied by the standard time. If we take, instead of the 60 pieces of output, the 30 pieces per hour as the basis of cost accounting, we can immediately see that the benefit for management comes from the cost saving associated with the system and from the orderly flow of production, reduced overtime work, maintenance of customer goodwill, orderly scheduling, orderly deliveries according to promises, etc.

It is true the company is paying 15% more, but it gets 50% more pieces per hour. Let us look at our arithmetic. If we paid \$1.50 per hour on the job in question, we were paying \$1.50÷30=\$0.05 a piece. With the incentive system, provided the desired schedules are met, we would pay the employee 15% more than his day rate, or \$1.725. If we divide this amount by the number of pieces produced, the labor cost per unit has been cut to somewhat less than 3 cents. In other words, even though more was paid in wages, we cut the unit cost from 5 to somewhat less than 3 cents.

Incentives and Flow Control

Assuming availability of accurate time study data and a wage incentive system, the task of scheduling is greatly facilitated. Now when the production control department states a delivery date, one can be reasonably sure that delivery will be made. The wage incentive system guarantees that employees perform up to their normal abilities. Being able to schedule production on the basis of expected output data, the headaches from uncertainties are greatly reduced; although, of course, machine breakdown or absenteeism may still interfere with production. When the schedules are based on wishful thinking, the whole scheduling and production planning procedure can easily be jeopardized. Incentives, on the other hand, occasionally improve the expected results. But improved results should be considered by-products, not virtues, of incentives. Any enterprise which hopes, through the wage incentive system, to raise production in the *absolute sense,* that is, hopes to obtain higher output than the time standard would ordinarily imply, is toying with unrealistic ideas. Incentives, as this author sees them, merely stabilize output at the normal output level.

SUMMARY

WORK SIMPLIFICATION AND STANDARDIZATION

Because a greater degree of perfection of the production process may be desirable, the process sheet is further improved by methods engineering. The final result is then costwise the best, though not necessarily technically the best, production process.

Methods planning fulfills several needs. First, it results in an improved production process and, second, it standardizes the methods of performance. The latter is important from the point of view of work measurement (time study).

TIME STUDY

Although the production process must be known in order to schedule work through the plant, merely knowing the path the material follows is still inadequate for scheduling. Scheduling—setting the starting and finishing dates on production—also requires knowledge of operation times. This can be had through a direct time study or through predetermined time standards. Once the time is established, then it can be calculated how long one operation will be and how long the production process as a whole will take.

In intermittent job shops, however, it would be difficult to first make a time study and then schedule production. Because the size of the order is usually small, the contract might be closed out almost faster than time study data could be developed. In order to schedule production without the aid of direct time studies, management practice has developed two other time study methods, namely: statistical (historical) time study and synthetic time study. The former is an estimate of the time requirement based on historical production data (past production records and man-hours of labor requirements), and the latter is based on previous time studies.

Since in many job shops the nature of production may be such that time requirements on given jobs will resemble one another, it is perfectly safe to base production schedules on past performance times. Whether we base production on the total hours required to produce a ton of x item or a gallon of y item is immaterial as long as a definite relationship exists between past performance times (per ton or gallon) and present plant efficiency. In some other types of companies the time requirements per operation may be partially the same but certain elements of the job will vary. Here a synthetic time study procedure is applicable. A case in point is a drilling operation. While the motion elements of drilling operations do not necessarily change, the number of holes drilled will cause changes in time requirements. Thus, to drill 10 holes instead of 5 will mean that the drilling aspect of the job will double. If performance times on such elements as "reach for material," "deposit material," "drill one hole," "drill 5 holes," etc. are available, it is possible to predetermine operation times and thereby facilitate production scheduling.

ENFORCEMENT OF PRODUCTION QUOTAS

Production scheduling would not make sense if schedules were never accomplished. Thus, when a schedule is turned over to operating management, the plan should be sufficiently realistic to be realizable.

Even though a production program developed by the production control department may be undoubtedly feasible, unless the supervisors can persuade people to perform to the schedule, production will fall short of expectations. To avoid having to rely solely on employee goodwill, wage incentives are developed to persuade employees to perform at their maximum. It probably means higher wage rates, but lower costs per unit of output; yet the incentives make the attainment of production goals possible.

QUESTIONS

7-1. Which activities can be classified as industrial engineering activities?

7-2. In what sense are the industrial engineering activities planning functions?

7-3. What is the relationship between the process and methods planning activities and the production planning function?

7-4. How is process planning related to methods planning (work simplification)?

7-5. Is there a difference between methods engineering and work simplification (motion study)? If so, what is the difference?

7-6. What is the function of the methods department?

7-7. How is the methods planning function carried out?

7-8. What kind of educational background must a methods engineer possess?

7-9. What are the functions of charts used by methods and motion study experts?

7-10. What are some of the principles of motion economy?

7-11. Why are charts used in methods planning?

7-12. To what extent are motion study and time study related?

7-13. How would you approach a time study project in a plant where you are not intimately acquainted with the various jobs awaiting time study?

7-14. How important is methods standardization in modern industrial production?

7-15. What role may methods standardization play in synthetic time studies?

7-16. How careful a methods study (that is, motion study) should be made in an intermittent job shop engaged in the production of specialty items?

7-17. Why is time study necessary to industrial production planning?

7-18. Could accurate scheduling take place if time study data were not available? Explain.

7-19. Would the method influence performance time?

7-20. How much freedom should be granted to the worker to develop his own method?

7-21. In how many different ways can time study be used in incentive development?

7-22. How is time study done?

7-23. What are the measuring tools of the time study engineer?

7-24. What is the difference, if any, between direct time study and derivative time study?

7-25. Does it make any difference whether the time study man utilizes a stopwatch, a time study machine, or a micromotion film with frame counter to determine the time value of each element of a job? Explain.

7-26. What kind of derivative time studies do we have?

7-27. What use is made of the various derivative time study data?

7-28. What kind of time study is needed in the intermittent production of specialty items ordered frequently and in very small quantities?

7-29. If the time study man uses the continuous timing method to establish time values, what chances are there to commit a grave error?

7-30. Differentiate between the snap-back and the continuous timing method of stopwatch time study.

7-31. What are the three basic steps of time study?

7-32. What is meant by synthetic time study?

7-33. Explain the function of rating.

7-34. Explain the function of allowances.

7-35. Illustrate the mechanics of rating and allowance calculation.

7-36. To what extent is rating controversial?

7-37. How could rating be improved?

7-38. What is meant by a "normal worker?"

7-39. To what extent can human performance be standardized?

7-40. Why must the job cycle be divided into motion elements in time study work?

7-41. What is wrong with measuring the work cycle rather than its motion elements?

7-42. What is meant by "incentive allowance?"

7-43. How is the development of wage incentive systems connected with time studies?

7-44. Can the output quota be calculated on the basis of the time study data? Explain.

7-45. Can piece rates be calculated on the basis of the time study data? Explain.

7-46. To what extent is reward or punishment used in a) a piece-rate system and b) a wage incentive system?

7-47. How does management determine the "allowance factor?"

7-48. How does management determine the "incentive allowance?"

7-49. What is the historical (statistical) time study procedure?

7-50. What is the value, if any, of statistical time standards in production planning and control work?

7-51. How accurate should time study be?

7-52. How can human judgment be eliminated in pace or effort rating?

7-53. What is the function of wage incentives in job shops?

PROJECTS

7-1. Assume that you are invited by a manufacturing company to set up a time study system on all the jobs in the company. The firm is engaged in the production of replacement electric motor coils. Although there is a great deal of similarity between field and armature coils, no two orders are exactly the same. However, repetitive orders are quite frequent. Most orders call for a set of repair or replacement coils. Describe how you would approach your work as a consultant.

7-2. If a company engaged in one or more extractive, analytical, synthetic, fabricating, or assembling operations wants to standardize its methods of production, what kind of charts should it use for the purpose of methods analysis?

7-3. Describe the time study procedure you would use in the coil replacement business to study the individual work stations; describe your approach to determining the processing time for each item produced.

7-4. Assume that a given operation consists of four elements. The elemental times are as follows: I=0.54, II=0.28, III=1.73, IV=0.39. The pace-rating factors are I=55%, II=130%, III=145%, IV=100%. If the allowance factor is a flat 10%, what is the standard time?

7-5. Determine the minimum output requirement for the purpose of wage incentive payment on the following milling machine job:

Elements	Time Value	Rating Factor	Allowances	Incentive Allowances
I	1.74	130%	7%	30%
II	0.55	125%	5%	30%
III	1.32	110%	7%	30%
IV	1.44	100%	5%	30%

7-6. Use the information given in Project 7-5 and determine accurately how long the job would tie down the milling machine, assuming that 3700 is the number of pieces to be produced and is also the output quota to be told the worker.

7-7. If you were to set up an incentive system in a company where it is essential to shift employees frequently from one job to another, how would you administer the program a) to have the least cost as far as administration is concerned, and b) to prevent employees from reporting a larger quantity than they have produced?

7-8. Describe the general relationship of methods standardization, time study, scheduling of production, wage incentives, and the function usually fulfilled by the timekeeper.

7-9. If the employees of a company are determined to defeat the purposes of time study, what measures can the time study engineer put into effect to offset their attempts and arrive at correct time studies in spite of a general opposition?

7-10. Describe the difficulties with scheduling if time study data are either inaccurate or correct but not enforceable.

CASES

7-1. The Hoppers Company, Inc.

In its ten operating divisions, the Hoppers Company, Inc. is engaged in the production of wood preservatives, synthetic chemicals, plastics, complex coal-tar combination chemicals, and a great many fabricated metal products. These products are sold in both domestic and foreign markets. While both the income and the growth potential of the company are great, unless certain inefficiencies are eliminated in the various subsidiary companies, the combined balance sheet of the company will not reflect the same success that has been registered in past years. The causative factor is, of course, the extremely small profit margins before, but particularly after, taxes of recent years.

Production in the company's two fabricating divisions will be discussed presently. Both of these divisions are operated as intermittent job shops, even though one of the plants could be considered as being engaged in repetitive manufacture since it handles repeat orders in relatively large volumes. The two divisions in question manufacture custom-made items ranging from experimental landing gears and missile components to intricate parts used in highly specialized machinery. Although both plants can handle the same type of contract, each has over the years developed certain skills making it more efficient in certain types of work.

The two plants operate independently in two different parts of the country. This supposedly permits a better distribution of work loads and serves two different geographical areas. Orders are usually, but not necessarily, assigned by the home office to that plant which lies closer to the point of delivery. Accordingly, the central production control department operating from Chicago, Illinois, tends to allocate work so that both plants are kept evenly busy. As a rule, an order to be delivered in Chicago or the Midwestern territory is turned over to the South Bend, Indiana plant, whereas East Coast orders are usually given to the Valley Forge, Pennsylvania plant.

The dividends paid in 1961 by the Hoppers Company were the lowest in the history of the company. Although this was predictable in view of the falling earnings of the last few years, the fact that company earnings in 1961 had taken a nose dive still came as a surprise. Because of sustained low earnings, the board of directors were not in agreement on the course of action the company should take. The chemical end of the business was relatively good, though earnings had severely declined despite a substantial rise in sales. The manufacturing end of Hoppers' business, however, became less and less profitable. Of the two manufacturing divisions, the Valley Forge plant barely broke even during the fiscal year of 1961. The vice-president of the Valley Forge plant, who as a member of the executive committee had considerable weight in the company, proposed ways and means to improve the efficiency of both metal-fabricating plants. The first step in this direction was to be a study with a view to discovering the sources of inefficiency in the fabricating plants. The investigations subsequently introduced revealed that productivity in the Valley Forge plant was considerably greater than that of the South Bend plant. This was reflected both in the overall costs and in unit costs. Despite comparable plant capacities, the Valley Forge plant has been able to turn out a substantially larger volume of business than the South Bend plant.

Although production control attempted to distribute work loads evenly, the study brought to light that the preponderance of all precision work was allocated to the South Bend plant, even though the Valley Forge plant was often much closer to the customer's location. It appeared, therefore, that manufacturing in the South Bend plant was primarily the special-order work in small quantities. Conversely, the assignments allocated to the Valley Forge plant seemed more of the repetitive variety requiring the employment of mainly semiskilled labor.

Whereas the workers in the South Bend plant were paid by a measured day rate, the Valley Forge plant operated under the piece-rate system. Before production standards and piece rates were established at Valley Forge, production methods were always carefully analyzed and improved. It was believed that the financial incentives encouraged workers to increase their productivity with considerably greater success than slave-driving could ever have accomplished. Plant management at Valley Forge contended that the piece-rate system could be credited not only with the lower operating costs but also with providing the basis for an orderly flow of production (achieved through scheduling) and completion of orders always on time. It also made for ease of supervision and provided for a better utilization of plant capacity.

The administration of the piece-rate system was relatively simple, though some snags had always to be removed. But once the method and the operation time was standardized, piece rates could easily be calculated. Since throughout Hoppers periodic job evaluation projects were undertaken to eliminate wage inequities, wage rates were based on the latest job classification. Once a given job was bracketed or reclassified under a certain job class, based on skill, accuracy, difficulty, etc., a piece rate was established on that basis. A simple division of the wage rate for that job classification by the hourly output quota gave the piece rate. Nevertheless, since the methods, the use of tools, and many other circumstances were always in a constant flux, foremen had to be very careful that every job was always classified by the right job and wage scale. This frequently caused arguments, particularly when the job was done again and again in rapid succession. Employees usually remembered the piece rate paid on the job when it was done at an earlier time; and if the new rate was lower, the employee assigned to the job wanted to know why. It was difficult to explain to workers that since the same job had been run years before, the tools used had been substantially modernized and improved. Thus, the job no longer required the same amount of skill and time and therefore no longer warranted the same amount of pay.

When time study revealed that a job should take 1.00 minute, the output quota was $60 \div 1.00 = 60$ pieces. If the job class paid $1.80, the piece rate was $.03. A worker producing 100 units an hour during an 8-hour day would earn $24 per day. When he produced only the normal 60 pieces per hour, his daily income would be only $14.40. When he produced less than 60 pieces per hour, his income would be proportionately less. Company management believed that productivity was the true basis for income differentials, and this system—as long as it remained fair and consistent—produced the expected results. After the standard had been established and piece rates were put into effect, it was essential to maintain normal working conditions. If they went out of focus and earnings diminished, dissatisfaction among employees would follow. To keep workers happy—and keep productivity up—it was one of the important tasks of supervisory personnel to see to it that delays due to material shortages or machine and tool breakdowns were prevented. Since management offered no guarantee of the base rate (that is, there was no payment unless workpieces were delivered), if the machine was down (idle), a great deal of pressure was put on supervisory personnel to find other work in order to maintain normal work flow. In this way, the system used at the Valley Forge plant developed a serious interdependence between supervisors and workers. Without thoughtful supervision, the worker could not make out, and this meant that foremen were under constant pressure from both labor and management.

Production control's schedules had to be maintained. The company contended that by this method it was possible to get good foremanship, high labor productivity, and low costs of operation; and, what was more important, orders were always delivered on time. The piece-rate system helped supervisory personnel accomplish production schedules set by central production control on the basis of the predetermined time standards. If schedules were beaten, there were always some fill-in jobs which the foremen could quickly assign to men and machines. Fill-in jobs were those which had very liberal delivery schedules; they were scheduled not by the central production control department but by foremen. The more fill-ins were completed, in addition to the normal work loads, the better the supervisor was in the eyes of higher management.

The method used at Valley Forge seemed to be excellent, and the new board member pressed for adoption of the same system in the South Bend plant. He contended that its adoption would bring productivity of South Bend up to par with Valley Forge and raise profitability of that plant.

The drive to increase company efficiency and productivity was universal. Investigations went on in each of the company's major divisions. The preceding case was emphasized because this was the first organized attempt under the company's housecleaning program. Unless the Hoppers Company showed more profit, the trade value of the shares of stock of Hoppers on the stock market would continue to fall. This might prevent future acquisition of capital, so vital to expansion and company success. This is particularly important because out of an authorized 2 million shares, only 1 million has so far been issued.

One of the basic problems of the piece-rate system was the setting of standard times. Since the Valley Forge plant primarily handled jobs of a repetitive nature, it was a common practice to send the special projects and more complicated jobs to the South Bend plant. Repetitive jobs, though produced intermittently, lent themselves better to time studies than the unique jobs did. Since customer specifications given to the South Bend plant were very rigid, care had to be taken that the products completed were not out of tolerance. A ruined workpiece would mean a loss of several hundred dollars. This was one of the many reasons why the plant employed skilled craftsmen instead of the semiskilled operators employed by the Valley Forge plant. Although the various operations performed in the two plants were similar, South Bend's operations were more exacting and were correspondingly more complicated than those performed in the Valley Forge plant. At South Bend, the determination of operation times was difficult because the primary basis was past experience with similar jobs. Time study men had to make allowances for certain variables, such as setup time, tool breakage and change, and oiling of tools, and for various difficulties resulting from small flaws in the metal to be worked with. A few little imperfections and impurities in the metal could cause breakage of tools. Actually, time standards were based on accumulated standard times from previous years for certain basic operations. These were then manipulated by the time study man in such a manner that a reasonable time standard was established. This method was referred to as synthetic time study. Anyhow, since contracts at South Bend seldom called for more than one or two pieces, it would have been wasteful to study each job individually. By the time the study had been completed, there would have been no need for the standard (except for some possible future time when some of the elements of the same standard could be reused). Even though these standards were not 100% accurate and further adjustments were often necessary to accommodate certain exceptional conditions, they were quite useful. If an employee found that the setup (which was calculated as a part of the standard time) was particularly difficult, he reported that to his foreman and asked for an adjustment of the time standard. The foreman discussed the setup with the worker and, if the request was justified, approved a greater setup time. It had been felt by the South Bend plant that the employees earned approximately the wage rate which was established by job evaluation (and the resulting wage scale) for the type of work they performed. Those who produced consistently above the predetermined standard were compensated through merit increases. Despite lack of wage incentives other than measured day rate, the merit rating offered adequate inducement to workers to work hard. While an employee's income depended largely on the opinion of his foreman, employees were satisfied with the merit rating system. Foremen were fair and rated employees fairly on the quarterly merit rating days. Thus, merit increases were, in effect, much like piece-rate earnings. Indeed, comparison of earnings of workers of comparable caliber showed that the earnings in the two plants were similar.

Despite success with the measured day rate, the South Bend plant often failed to meet important shipments. If customer complaints were registered at the Chicago home office, nine times in ten the cause of complaint was in South Bend. While the central production control department had difficulty with the South Bend plant, it usually had no trouble with Valley Forge. In the former, schedules had to be adjusted quite frequently and the situation was sometimes so bad that all South Bend schedules were considered as being temporary until the shipment was finally made.

Although it was recognized that the success with the piece-rate system in Valley Forge by no means implied that similar success would be achieved with it in South Bend, it was generally assumed that a piece-rate system in South Bend would bring about a more orderly flow of production, facilitate scheduling by the central production control department, and greatly facilitate supervision. However, the problems in conjunction with the introduction of the piece-rate system would seriously disturb current peace between the labor union and plant management in South Bend. It was believed, however, that the ease and lower costs of supervision would more than compensate for some of the advantages of the measured day rate. Employee income might also rise.

Production volume at South Bend, although allegedly 90% of capacity, was considerably lower than that at Valley Forge, where production had controlled itself to some extent. At South Bend, foremen had far more power in making decisions on changes in schedules and concessions in wage compensation (as far as production standards were concerned) than at Valley Forge.

At Valley Forge, the departmental foremen frequently supervised over 40 employees, yet did not feel as busy as the foremen in South Bend who, under the measured day rate system, found it difficult to direct 10 to 15 workers.

The question whether the wage payment system in operation at the Valley Forge plant would precipitate favorable results if introduced at the South Bend plant had to be answered. It was reasonable to assume that the piece-rate system of the Valley Forge plant was more of an incentive system than South Bend's measured day work, mainly because inadequate output as measured by the standard output was penalized. Furthermore, as the system operated in South Bend, any worker who felt that he could not possibly meet the standard could go to his foreman and find some pretext for an adjustment of the time standard. Since setup is not an exactly measurable time, any extension of the setup time would ipso facto cause an actual "softening" of the time standard.

Those arguing against the idea stated that the many different specialized orders manufactured at South Bend in small lots would require a large number of time studies and a great deal of industrial engineering time to set standards accurate enough to serve as a basis for piece rates. If the worker could not meet the standard and could therefore not keep up his piece-rate earnings, he would complain and blame inadequacy of the standard rather than his own inability. This statement implies that the standard was always accurate and the worker inefficient, but often the reverse would be true and the standard would be at fault. Obviously, it would be difficult to set accurate piece rates on typical, highly skilled machine operations customarily assigned to the South Bend plant. The employee who felt that the standard was unfair would get into a lot of arguments, file grievances with his labor union, and make a lot of fuss about a few pennies. Simple problems, as they were being handled, would become big issues and bring the labor union into the plant every time something was—or allegedly was—wrong with the rate. Lengthy time studies would be forced upon management to prove to the union that the standards were fair and equitable. Therefore, it was argued that the present system of measured day work was better suited to South Bend's operations because it required little effort in time study. Furthermore, payroll calculations were correspondingly easier. Piece-rate calculations would require a score of timekeepers, and employees would waste a great deal of production time on counting and checking the number of pieces they produced.

The plant management considered the measured day rate to be a good system which truly motivated employees in that it offered a high rate of pay to employees after a period of consistently high production or overproduction as observed by the respective foremen. But it was not as quickly related to output of the worker as are piece rates, which tend to fluctuate daily with the worker's production. Moreover, the basis for performance rating (the criterion for merit inceases) of the employee on the measued day rate is partially subjective; whereas the quantity actually delivered is the basis for the piece-rate pay. Workers quickly call the foreman's attention to nonstandard conditions to prevent their piece-rate earnings from falling. With this cooperation of the workers, less supervision of detail is required. In addition, employees derive a sense of responsibility and satisfaction. Thus, supervisors can take care of stricter schedules. On the other hand, the measured day rate permits quicker introduction of better methods and processes because red tape is fully eliminated. Both systems have merits; in a sense, both were suitable to the conditions existing in the respective plants.

In many quarters it was thought that the problem of rising production cost and falling profit margins might lie in other than the wage payment area and, if so, company experts should discover whether production scheduling, time study methods, inventory control, or some other factor was responsible. It was entirely possible, of course, that better and stricter scheduling and associated process and methods planning could solve the production problem faster, and more decisively, than a change of the wage payment system. Some arguments ran that a change in the system of wage payment might impose added costs not quite commensurate with the savings expected and therefore ought to be looked into before a final decision was made.

Questions. The student should be reminded that the problem involved hinges upon deciding whether the production problem (handling less production volume than the other plant and having higher production costs than the other plant) is really related to the wage payment method. Apparently, the crux of the matter is that wage payment is closely related to production scheduling. A schedule, in turn, apparently has little or no meaning unless it is based on rather accurate time studies. Correct time studies will usually permit reasonably good schedules. However, even the best schedule, despite excellence of supervision, is useless unless one can rely on the cooperation of workers. "Incentives" are incentives only if the workers consider them such and perform according to schedule. If production schedules are accomplished and the schedules were based on correct time standards, then the costs of production tend to be low.

1. What symptoms indicate that the company has a production problem?
2. What seems to cause these symptoms?
3. Is it possible to eliminate these causes without recourse to a piece-rate system?
4. Would the Valley Forge plant's piece-rate system solve the productivity problem in the South Bend plant?
5. Would the nature of production make a great deal of difference as far as the workability of a wage payment system is concerned?
6. If your decision on Question 3 is negative, under what conditions could the Valley Forge system also work in the South Bend division?
7. Test whether or not the wage payment system in the Valley Forge plant is really as excellent as claimed by its proponent.

8. If your answer to Question 3 is affirmative, explain how you would implement the system with regard to both administration and cost.

9. List the shortcomings of the Valley Forge plant and relate them to conditions existing at the South Bend plant.

10. Examine critically the various opinions expressed in the case.

7-2. Tropical Shirts Incorporated (Part II)

Tropical Shirts Incorporated is a relatively small shirt manufacturer. It specializes in the production of low-priced sport shirts which are sold throughout California. The plant of the company is located in a two-story building on the outskirts of Los Angeles. In the past the company made good profits in the face of serious competition, but recently, despite an increase in sales, profits have substantially declined.

Tropical Shirts Incorporated originally operated under the bundle system of production. According to this system, production of 10 bundles of shirts was carried out in the various departments, each of which performed a given operation in a predetermined sequence. The company had a limited number of employees who were capable of performing several different operations in the shirt-making process. When 10 bundles of shirts were completed in a department, all shirts in the bundle (a bundle is a convenient production lot of 10 dozen shirts) were sent to the next department.[7]

The company has always developed its own production process and plant layout. When drastic changes in the production process occurred and output had to be measured by time studies, Haskell-David-Ferguson and Associates were usually called in to perform the time study.

Although Tropical Shirts Incorporated resisted drastic changes in production methods for years, competition forced a changeover from the bundle to the more efficient production line system. This required that succeeding operations be lined up and located beside one another. As the employee completed the operation on a shirt, the next employee received it. If work stations were properly synchronized, the shirt moved in a continuous stream along an assembly line even without the benefit of a conveyor system.

The company's owner, with the help of some of the supervisory personnel, worked out a new plant layout and production system patterned after the progressive assembly of television chassis that Mr. Goldfinger had recently observed. After acquiring several additional machines and remodeling the plant's wall structures, the line system was introduced.

In the first week the production flow was not as smooth as originally anticipated and bottlenecks were apparent at several work stations. These bottlenecks were first attributed to inexperience of the newly hired girls. It was soon recognized, however, that these bottlenecks were caused not by inexperience, but by a definite unbalance in the production line. Although some company officials were not in favor of calling in a consulting firm to determine the process, company management finally decided to get some outside help. Management specified at the outset, however, that the function of the consulting firm must be confined to establishing time standards on individual jobs. If time study revealed unbalance, rearrangement and improvement were to be handled by company supervisory personnel rather than by the consulting firm.

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[7] For additional information as to the company's operations, see Case 6-2.

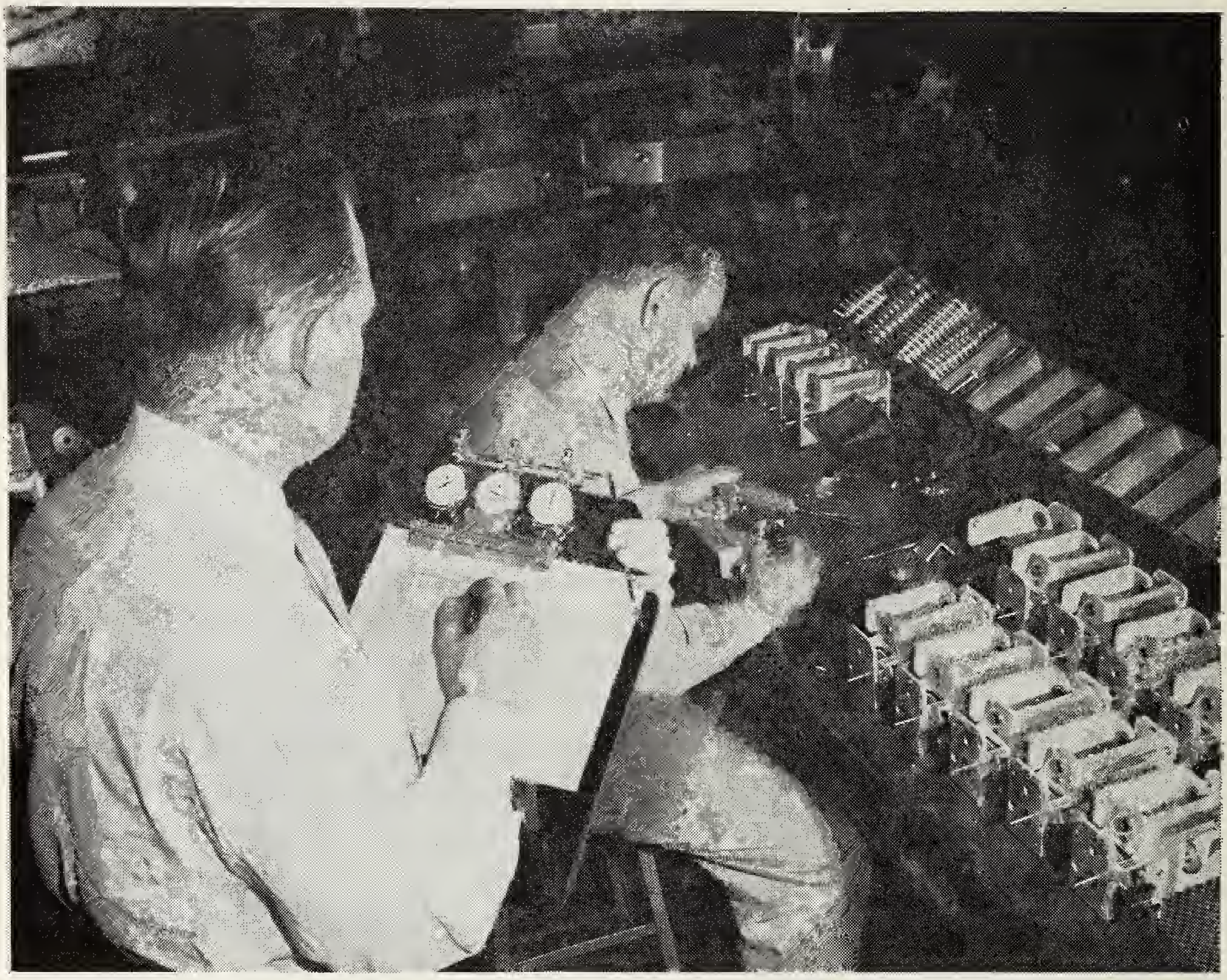
Haskell-David-Ferguson and Associates sent out to the Tropical Shirts Incorporated a young industrial engineer who was specifically employed for time study purposes. The industrial engineer walked around the shop and, after visiting there for an hour or so, sat down for a conference with company management personnel. During the course of this conference he stated that before he could set production standards on every job in the plant, he must know exactly what was going on in the shop. Therefore, he intended to make a process analysis. He stated that this would take quite a long time, but once he had made a process analysis he could quickly set the time standards.

Mr. Goldfinger, the manager, became very suspicious and said immediately that Tropical Shirts Incorporated had not asked the consulting firm to analyze their production methods, but had merely asked them to set time standards. "What we have in mind," stated Mr. Goldfinger, "is that you take your stopwatch and make the necessary time studies. Never mind our process."

The young time study expert insisted, however, that he still wanted to make a process analysis and if the company did not want *him* to make it, then a member of the company should write down all the jobs along the contemplated production line in a sequential as well as a chronological order. He showed a sample process sheet on which another company had listed the various jobs and the motions involved in them. At the end of the conference, the time study man promised to be back when this information was available for him.

A month or so later, the industrial engineer returned. Now he walked around in the shop with a process flow chart in his hand. When noon came, he left and did not come back at all during the following week. Mr. Goldfinger phoned the consulting firm several times and was told that "we are working on the contract." Another week passed and Mr. Goldfinger still heard nothing from the consulting firm. He threatened to cancel the consulting contract. Subsequently the young industrial engineer came out again. As before, he went through the shop, but this time he studied the various jobs for a few minutes. According to Mr. Goldfinger, he did not spend more than five minutes at each work station. The time study expert carried a clipboard with three stopwatches attached. With this he studied every job for a few minutes, then he left again. When he returned 4 days later, he left a 40-page report with Mr. Goldfinger. (Part of this report appears as Exhibit I. Read it carefully because it may shed light on important problems involved in the synthetic time study procedure.)

The time study data which the consulting firm presented appeared to be perfect. The time discrepancy between certain work stations as revealed by the time study clearly indicated the nature of unbalance in the plant layout and the reasons for the lack of a perfect production flow. From the time study data, the company could immediately see why at given work stations bottlenecks were developing. Thus, the management of the Tropical Shirts Incorporated was happy with the accuracy of the time study. On the basis of the information, the various operations were adjusted. Since the production line operated on a 1-minute cycle, operations were grouped to take 1 minute. If the time was less than 1 minute on any given operation, additional tasks or motions were assigned to that work station. These additional motions were taken away from a preceding work station which possibly exceeded the 1-minute limit necessary to an orderly flow.



Courtesy E. A. Cyrol and Company

After making these adjustments, the line was balanced and production flow became smooth. The production of sport shirts became extremely profitable. The new system of line production has substantially reduced the unit costs of production. At the same time, the quality of production showed marked improvement. During the past few years—under the pressure of competition—company management had attempted to meet competition by a reduction of shirt quality. Thus, seams became wider, buttons looser (that is, they were sewn on with two or three stitches), right-hand pockets were eliminated, etc.

The contentment with the time study stopped, however, when Mr. Goldfinger received the bill from the consulting firm. Mr. Goldfinger kept saying "there must be an error." Finally, he phoned the consulting firm to ask for a verification of the bill. It was indeed an exorbitant price for three half-day's work, and he threatened not to pay it.

Mr. Haskell, the senior partner of the firm went to see Mr. Goldfinger. He explained that the time study which his firm had made was a different method of time study than they made previously. In the past his men used to take time studies with a stopwatch and spend a considerable amount of time on company premises. This time, however, the company employed the elemental times method of synthetic time study. In other words, the time study expert developed time study data for the various operations on the basis of predetermined times for the motions involved in the jobs. Mr. Haskell explained that during the past ten years, Haskell-David-Ferguson and Associates had spent thousands and thousands of dollars in developing logarithm-like tables with motion time values on various sewing operations involved in shirt making. By using these tables, four of his men were working day and night on the Tropical Shirts Incorporated contract. Not only was this a time-consuming job, but it required highly skilled personnel.

Mr. Haskell explained further that the time which the industrial engineer spent on company premises was a very small portion of the consulting firm's expenses. The industrial engineer went to the plant merely to familiarize himself with the operations and to check the accuracy of the standards. Thus, the consulting firm charged not so much for the time which the industrial engineer spent on company premises as for the skill needed to develop synthetic time standards. The research expenses, the skill and time to make the study, etc. have to be paid by customers. Mr. Haskell stated that this method of developing time standards was much faster and much more exact than the stopwatch time study method. Tropical Shirts Incorporated, he said, should be happy that it was dealing with Haskell-David-Ferguson and Associates, because the time study data which it received reflected the general production pattern in the shirt industry. Haskell-David-Ferguson and Associates collected, through their New York office, time study data in the garment district of New York, and the time study had used all data which were available from other studies.

Finally, the bill was paid and Tropical Shirts Incorporated operated very profitably. The time study was as perfect as any time study can be, which was manifested by the perfect flow of production. The costs of production went down more than the company had originally anticipated. In other words, the time study paid for itself within a short period of time. Although the price paid for the time study appeared exorbitant at first, the company began to recognize the tremendous value of the time study for future profitable operations.

EXHIBIT I

To the Board of Directors
Tropical Shirts Incorporated
2788 Main Street
El Segundo, California

Gentlemen,

This report deals with time requirements on your production line of shirts, in general, and sport shirts, in particular. The time study herein contained is based on the principles of "elemental times" and reflects not only your operating efficiency but also that of other manufacturers engaged essentially in the same line of business.

These operation times, as listed on the Data Sheet, already contain allowances for fatigue and incidentals based on our verbal agreement. Accordingly, the elemental times, when tallied, contain 12.5% for the purposes mentioned above. In view of the intended purpose, no incentive allowance is given. Therefore, it is mandatory that your plant layout is arranged in such a manner that control over tempo of production is not influenced by employee likes and dislikes.

Since employees may have to leave their workplaces while the production line is in operation, satisfactory arrangements must be made to replace temporarily those employees who leave their workplaces to go to lunch, to the washroom or ladies room, etc. We suggest that employees verbally ask for replacement, but a light bulb switched on is the customary device which indicates that an employee requests replacement. In other words, it is important that the production line moves steadily and no employee leaves his workplace unless someone replaces him during the absence from the work station. For continuous and uninterrupted flow, it is essential to have certain employees whose skill will encompass all operations on your production line. Unless you seriously consider this suggestion, the time study data may not work out as it should.

Although we took your operating equipment into consideration, in order to compete with other firms in the shirt business, it is essential to consider the mechanizational differences between your plant and other plants. Therefore, please keep in mind that the acquisition of certain jigs, fixtures, and other attachments is necessary to be able to accept the time study data. Generally speaking, your operations, as observed by our time study man, indicate that only a few work stations must undergo serious rearrangement.

It is axiomatic that the use of faster, better, and more productive sewing machines results in greater manufacturing economies. In line with this reasoning we suggest that in your attempt to synchronize work stations with one another, not only the production flow be kept in mind, but also the cost amelioration to be associated with the balancing of the production line. The calculation is simple by the use of the formula

$$S = \frac{T \times N \times W}{V}$$

where S represents savings per 12 shirts; T the number of tacks per shirt; W the wage bracket into which the operator doing the job will fall, divided by 5 (To conform with machine speed units which are normally stated in stitches per minute, it is necessary to convert hourly wages to dollars per minute. This is accomplished simply by dividing hourly wages by 60. To relate production costs to 12 garments, a factor of 12/60 or 1/5 must then be applied to hourly wage rates); V represents the speed factor, that is, speed of faster machine multiplied by speed of slower machine, divided by speed difference between the two units.

Changing to a tack with fewer stitches will also result in savings, in addition to precipitating better synchronization of two or more work stations. It should be remarked, however, that by work station not one machine but possibly a group of machines is implied. The station should be capable of absorbing the work load of the previous work station O, which in turn, might also consist of one or more machines and operators. Furthermore, quality cannot be neglected since quality depends largely on the strength of the stitch—which in turn, depends on the width of the stitch in question. Considering all these factors, the question arises whether the x-stitch tack should be accepted in place of y-stitch tack. (For example, should a 36-stitch tack replace the 28-stitch tack?) Using the 42-stitch tack, in lieu of the 36-stitch tack, cost per dozen shirts can be cut by 2 cents. The resulting savings can be calculated as follows: multiply N (see the formula above, $N =$ the number of tacks per shirt) times W (one-fifth of the operator's average hourly wage), times D (the stitch-count differential between the old and new tacks). Then divide the result by V, the machine's rated speed.

$$S = \frac{N \times W \times D}{V}$$

In an assumed example this might be

$$S = \frac{24 \times 0.25 \times 6}{1700} = \frac{36}{1700} = 0.02$$

All these were mentioned here to show that the problem of synchronization can easily be combined with work simplification. Calculated savings can come from reduction of the machine cycle time via increased machine speed or via fewer number of stitches in the tack pattern, or both.

The following time study data are given in decimal minutes per one shirt. We believe that it is practical to work on a per shirt basis, although savings should be calculated in terms of dozens because your selling price is based on dozens. It is essential to check not only the time studies, but also the method by which savings can be achieved. As a rule, we have accepted your method, but as you will see we have occasionally considered your method obsolete and respectfully suggest improvements. We took the liberty of incorporating improvements in our time study data. If you should discover that your present operating efficiency on specific operations is drastically different from the time studies, we suggest you read the necessary mechanization instructions to accomplish that performance.

These improvements can be attained through a very nominal financial investment.

The following operation sequence follows a logical shirt development rather than the process on your shop floor. Please do not consider our sequence as a suggested cure; the sequence selected is merely a convenient one which has been used by other shirt manufacturers, and we have adopted it because it appeared convenient to us.

As stated at the outset, to meet some of these standards it is essential to use certain standard devices common to the industry. May we refer to reciprocating and slip stackers, automatic thread cutters and trimmers, needle positioners, edge beaders, pedestal mount and clamp tables, sequential buttonholers, automatic button sewers, slide knives, etc. If not already used, your consultants advise you to consider acquisition of these devices because of their ability to cut both operation time and costs. In addition, they help you adapt your operations to the competitive shirt business.

While the validity of the time standards given here have been proven, it is essential that employees follow the method generally described below. To avoid repetition, we have mentioned only those which represent a certain type of motion pattern.

Seaming Collars. At completion of sewing, the collar is parallel to the table. It then rests upon a flip stacker which, after release of the thread chain by an automatic cutter, flips 180 degrees to deposit the collar in a neatly arranged stack.

Topstitching Collars. This operation resembles seaming collars, but with one added factor—collar beader. This device takes the form of a cutting-knife blade which slides between the collar leaves, thereby forcing out the seamed edge.

Goring Sleeves. Although this is a simple motion, the use of a guillotine cutter and reciprocating stacker offers advantages. Upon completion of the seam, the thread chains are cut and work falls upon the stacker for perfect piling.

Yoking Backs. Since the machine is mounted upon a pedestal table making it possible to place the backs in a clamp table to the left of the operator, motions are saved and time requirements reduced. The clamp table is a wooden workhorse to the top of which is affixed a spring clamp. Before starting to sew, the operator should lock the tails of a bundle of shirts into the clamp and then fold the entire bundle back upon itself. This makes the bottom ply the first available for sewing. The operation then should be performed in the customary manner.

At the end of the sewing of each piece, a guillotine knife should be used to separate the thread. The completed back will fall against the clamp table. When all are completed, the bundle, with yokes attached, is restored to its original condition. It may then be retied or left on the table for interim storage.

Setting Pockets. The creased pocket is sewn in the conventional manner. The use of an automatic trimmer and a needle positioner would yield both a direct and a deferred advantage. The direct time saving will come as the automatic needle positioner removes the needle without any movement on the part of the operator. The deferred gain will result from the automatic trimmer cleaning all threads and from this advantage being passed along to the final inspection. The normal method is considerably less effective than this. Since your method does not coincide with this one, there is probably a discrepancy between your performance and our time study. Incidentally, this is a bottleneck in your production line.

Buttonholing and Button Sewing Fronts. The standard tandem buttonhole

OPERATION DATA SHEET

Operation (For suggested mechanization see accompanying methods description)	Standard Operating Time (Based on advisable mechanization and on your company's present practices)
collar	.2956
turn, trim, press	.2115
top stitch	.2295
shape bottom	.0909
band hem	.1755
set	.3555
turn, check ends	.1305
bead	.0909
trim	.1170
notch	.0855
buttonhole	.0585
sew buttons	.0585
cuff hem (line)	.2115
seam	.2115
turn	.1170
top stitch	.1755
buttonhole	.1305
sew buttons	.1305
gore sleeves	.2385
set facings	.2835
close and point facings	.8955
set label	.2555
set yokes	.2555
set button stay	.1395
center fronts	.2790
crease pockets	.1395
set pockets	.5355
buttonhole, sew fronts	.4095
join shoulders	.3825
set collar	.4275
close collar	.4275
set sleeve	.4275
close side	.4275
hem bottom	.3555
set cuff	.4275
close cuff	.4275
trim and inspect	.3555
press	1.0755
fold	1.0755
assort and box	.4275
interim inspection	.2655

arrangement should be replaced by a sequential buttonholer. Since your present method provides too large an output, it is suggested that sewing buttons on fronts should also be performed by the buttonhole operator. The button sewer is equipped with an automatic feed and is mounted upon a stand-up table. This will relieve the previous work station of some work; thus, both operations can be balanced without additional investment. Accordingly, the operator should be able to load the sequential buttonholer and then turn to the button sewer. Since buttons are sewn within the automatic buttonhole cycle, the latter output is a bonus.

Making Fronts. Although our time study is somewhat higher than the operation should take, it would not pay to change the operation in question since you specialize in sport shirts. If you want to enter a higher quality shirt market, we believe that the standard American center strip or plait front and lined stay side would be to your advantage. For this reason we provide you with the time standard applicable to this. If you want to adjust our time standard and continue use of your present front-making practices, deduct from the time .0772 and .0223. These are extra motion elements not contained in your present method. The center front is performed in the customary manner, with the cutting apart being done after sewing. By equipping the operation with an automatic stacker, slide knife, and needle positioner, operation time will not be raised despite the addition of two motions which permit production of higher quality.

Making Button Stays. This operation is treated in the same way as fronts but does not require a needle positioner.

Joining Shoulders. The use of a folder offers an excellent opportunity for job exploitation. A guillotine knife and automatic stacker should be added to the standard equipment. The machine must be set toward the back of the table so that the parts may fall freely after sewing. When each shirt is joined, the knife cuts apart and the stacker sweeps the garment away on to a neat stack.

Hemming Bottoms. This operation makes excellent use of the clamp table, pedestal mount, and guillotine. The stacked bundle is clamped to the table by the collars. The bundle is folded back to make the bottom hem available first. The pedestal mount permits the clamped bundle, as well as the operator, to be close to the needle area. The knife cuts clean at each seam and permits the completed shirt to fall. Thus, when the complete bundle is sewn, it is automatically returned to its original stacked condition.

Final Trimming and Inspection. This presents the greatest time-saving possibility. If the attachments suggested are used throughout, there is no remaining thread on the shirt to be trimmed.

Questions

1. What were the symptoms indicating that there was a need for time study?
2. What is the relationship between motion (methods) study and time study as indicated by the Tropical Shirts Incorporated case?
3. What were the factors causing these symptoms of inefficiency?
4. Is time study the answer to the problems experienced by Tropical Shirts Incorporated? If so, explain why. If not, explain the nature of your disagreement.

5. Would it have been better, as far as the company was concerned, if both motion and time study had been performed by the same consulting firm?

6. Do you agree with the time study method which the consulting firm employed, or would you say that a direct time study method would have been better?

7. What is the difference between synthetic time study procedures and direct time studies which Mr. Goldfinger does not seem to understand?

8. List the advantages and disadvantages of the synthetic time study procedure, as far as Tropical Shirts Incorporated is concerned, as opposed to the direct time study procedure, using the stopwatch as the measuring instrument.

9. Do you agree with Mr. Haskell's statement, "Your company should be happy that it was dealing with Haskell-David-Ferguson and Associates, because our time study data reflect the customary production pattern employed in the shirt industry"?

7-3. ASTOR COILS CORPORATION

Astor Coils Corporation is a medium-sized intermittent job shop engaged in the manufacture of field, armature, stator coils, and rotors. The coil, which is a part of an electric motor, burns out occasionally and must be replaced. The company specializes in the replacement-coil business rather than in the manufacture of coils on a large scale, although occasionally subcontract work or stock production takes place. This is usually during slack periods to even out order fluctuations. Eighty per cent of the company's business stems from steel mills, mainly from local mills and especially from those employing electric furnaces.

Coils and motors are produced by many different manufacturers, and the steel mills could go direct to those manufacturers for the coils needed for replacements. However, if the motor is older than, say, 10 years, replacement coils are no longer stocked; and although the prime producer may be willing to replace the coil, he is usually slow in shipments. This is where the replacement-coil specialist has the advantage. Astor Coils Corporation can and must, to keep customer goodwill, ship considerably faster than the prime producer. The prime producer is equipped to produce large volumes at low price but does not start production until he has accumulated a large number of orders to make a run worthwhile.

The key to success in this business therefore lies in the ability to make shipments within a week or so. Although the coil price is negotiated, the replacement manufacturer must usually charge the prime producer's list price, which is often inadequate to fully cover the costs of manufacture on a small order. The other complicating factor causing costs to rise is that quality is of extreme importance, because the coil must fit into the slots on the motor without being hammered into position.

The plant of the company was divided into two basic and several auxiliary departments. The production process was, however, pretty much the same whether for a field or armature coil (see Fig. 1).

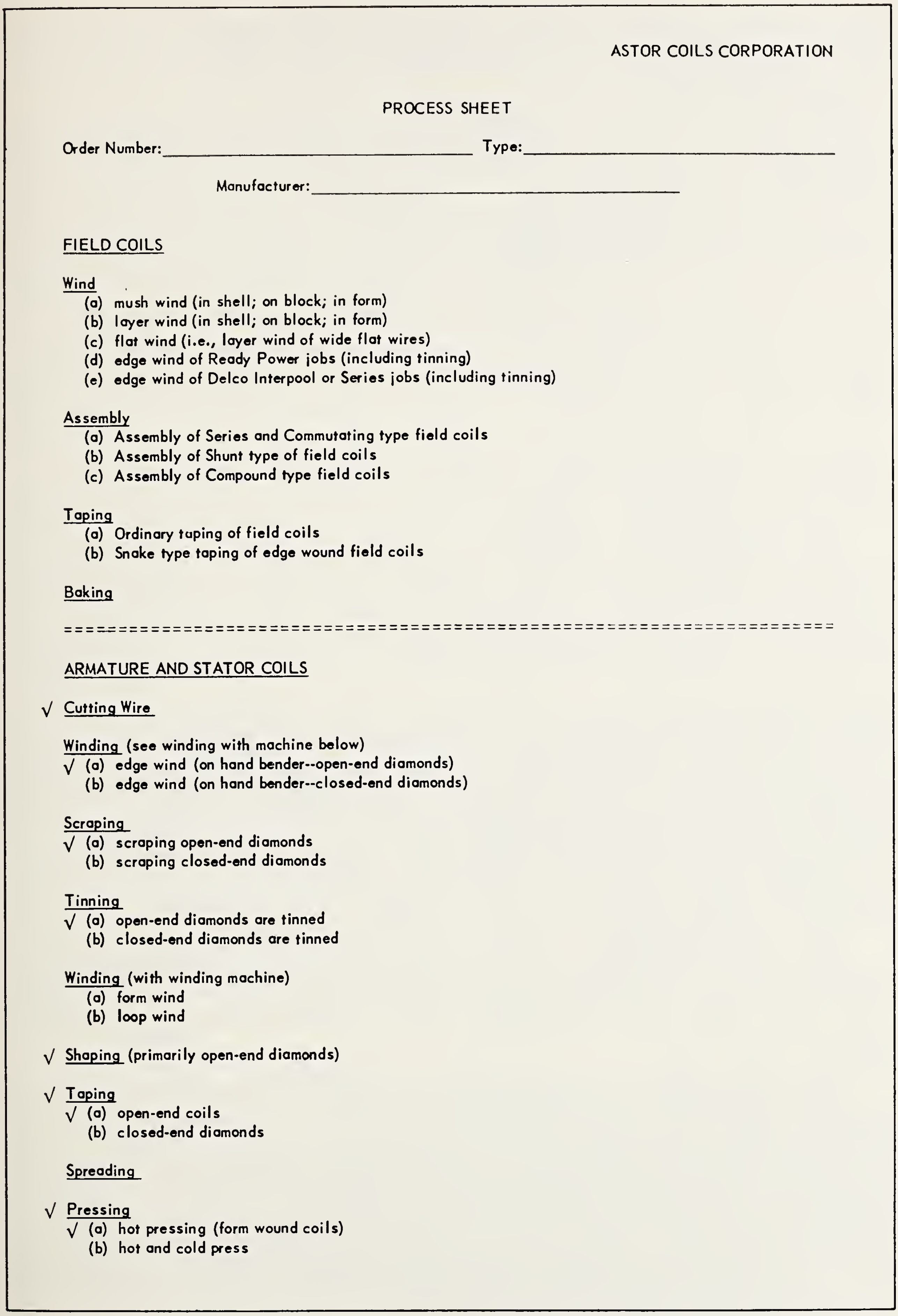
The superintendent's office, along with the offices of the foreman and engineers, was located in the middle of the shop on an elevated platform which gave an excellent view of the whole shop.

The operations of the company were tied closely to the steel industry in that a large portion of the company's customers were the steel mills. Therefore, if the steel business was good, the coil-replacement business was equally good. The coils are apt to burn out faster if the motors are in constant use. When steel production was low, but the company expected a pickup in the near future, it stocked some of the most common types of replacement coils. Thus, work loads could be spread over good and bad times and the company could even out employment for its approximately 100 semiskilled employees.

Although the company still operated profitably during the severe recession of 1960–61 the profit fell to an all-time low in 1961. The decline in profits was, however, only partly attributed to the recession. In the steel industry, which is by far the largest customer of the Astor Coils Corporation, there was a strike in the early part of 1960. During this period of poor business, it became clear that the company had been accepting orders which actually had cost the company more to fill than the customer paid. The list prices on coils were not uniform. Older types of coils sold at a relatively lower list price than newer models; yet if the company wanted to stay in business, it had to accept some bad jobs along with good, even if the list price was low. Since most firms in the coil-replacement business bid for jobs at the list price, it was essential to quote on that basis in order to land an order. Now that operating management was not as busy as usual, foremen found time to keep records. Even a superficial analysis of cost records revealed that approximately 50% of all jobs had cost the company nearly as much to do as the customers paid for them. On some orders the company actually lost money.

Although the president of the company was aware of the inequities in list prices, it was difficult to pinpoint in advance which jobs would and which would not be profitable. The company had never made a serious attempt at cost analysis. The president urged operating management to collect cost information, but the superintendent was of the opinion that record keeping would overburden his foremen and would not recover the lost money anyhow. A timekeeper, with the duty of collecting time information and relating time to output, had been suggested, but it was argued that the size of the plant did not warrant employment of a timekeeper.

Since the company ordinarily made a profit, the size of the profits absorbed these losses. Nevertheless, operating profits had shown a consistent decline ever since the first recession following the Korean War. While the company still earned 20% profit in 1954 and 1955 (one of the best steel production years due to the highest automobile sales in the United States history), its



ASTOR COILS CORPORATION

PROCESS SHEET

Order Number:______________________________ Type:______________________________

Manufacturer:____________________________________

FIELD COILS

Wind
- (a) mush wind (in shell; on block; in form)
- (b) layer wind (in shell; on block; in form)
- (c) flat wind (i.e., layer wind of wide flat wires)
- (d) edge wind of Ready Power jobs (including tinning)
- (e) edge wind of Delco Interpool or Series jobs (including tinning)

Assembly
- (a) Assembly of Series and Commutating type field coils
- (b) Assembly of Shunt type of field coils
- (c) Assembly of Compound type field coils

Taping
- (a) Ordinary taping of field coils
- (b) Snake type taping of edge wound field coils

Baking

==

ARMATURE AND STATOR COILS

✓ Cutting Wire

Winding (see winding with machine below)
- ✓ (a) edge wind (on hand bender--open-end diamonds)
- (b) edge wind (on hand bender--closed-end diamonds)

Scraping
- ✓ (a) scraping open-end diamonds
- (b) scraping closed-end diamonds

Tinning
- ✓ (a) open-end diamonds are tinned
- (b) closed-end diamonds are tinned

Winding (with winding machine)
- (a) form wind
- (b) loop wind

✓ Shaping (primarily open-end diamonds)

✓ Taping
- ✓ (a) open-end coils
- (b) closed-end diamonds

Spreading

✓ Pressing
- ✓ (a) hot pressing (form wound coils)
- (b) hot and cold press

FIG. 1

profit was only 12% in 1956 and 7% in 1957. At the end of the fiscal year of 1960 the company closed its books with only 1½% profit; in 1961 the company was in the red.

The steel strike and the beginning of a recession which happened to coincide played an important part in the loss of profit. Nevertheless, serious action had to be taken to arrest the declining trend. One important opinion was that the severe decline in company profitability was due only partly to the circumstances and was due mainly to excessive catering to customer's desires and, in particular, to an indiscriminate acceptance of orders. It was contended that many of the orders the company accepted in its desperate need for work were actually orders which other manufacturers had already turned down because of their low list prices. Hence, Astor Coils Corporation was unknowingly accepting orders nobody else wanted. Apparently, other companies had time study data available and on that basis could predetermine what price they should get for the work. Once preliminary calculations indicated that the list price was too low, these companies refused the order. It should be realized that the original motor manufacturer produced these coils with large-scale methods and, being tooled up for high-speed production, could make them considerably cheaper. The repetitive job shops, such as the Astor Coils Corporation, had general-purpose machinery, their setups were frequent, and their jigs and fixtures were not comparable in efficiency with those possessed by the prime manufacturer. Therefore, the original manufacturer was able to make a profit on these jobs even at low list prices. Furthermore, the list price was usually based on prices of the particular model year. Inflationary changes or changes in labor cost over the years were seldom considered in future quotations. The original manufacturer usually ran a surplus at the outset and could supply most replacement coils from stock. After a number of years, however, the stock was depleted and no large-scale manufacturer was willing to make a run for one or two sets.

Now that the problem, namely, that Astor Coils Corporation accepted many low-profit or no-profit orders during the poor business conditions of 1960 and/or 1961, was recognized, ways and means had to be found to solve it.

The first step toward a solution of the problem was the attendance of the company's office manager at evening classes at a local university to learn how to make time studies. After several weeks of study, however, he reported to the president that an evening course was inadequate. He could certainly spend some time during the day in the shop; but now that he knew so much more about time study than previously, he could foresee difficulties. To spend such time in the shop as the project would require would force him to neglect his office managerial duties.

In the meantime, business conditions had improved in 1961 and orders started to come in at regular intervals. The backlog of orders and the delivery requirements indicated that the backlog could be worked down only with overtime work. The treasurer warned the company that the situation would become even more serious if overtime work was applied to get things accomplished to meet customer delivery schedules. It should be noted that any hours worked in excess of 40 per week would be compensated by time-and-a-half pay. This meant that the bad jobs would lose even more money and profit margins on the good jobs would become even smaller. Since labor costs made up 60 to 70% of the company's total costs of production, extreme care had to be taken with overtime work.

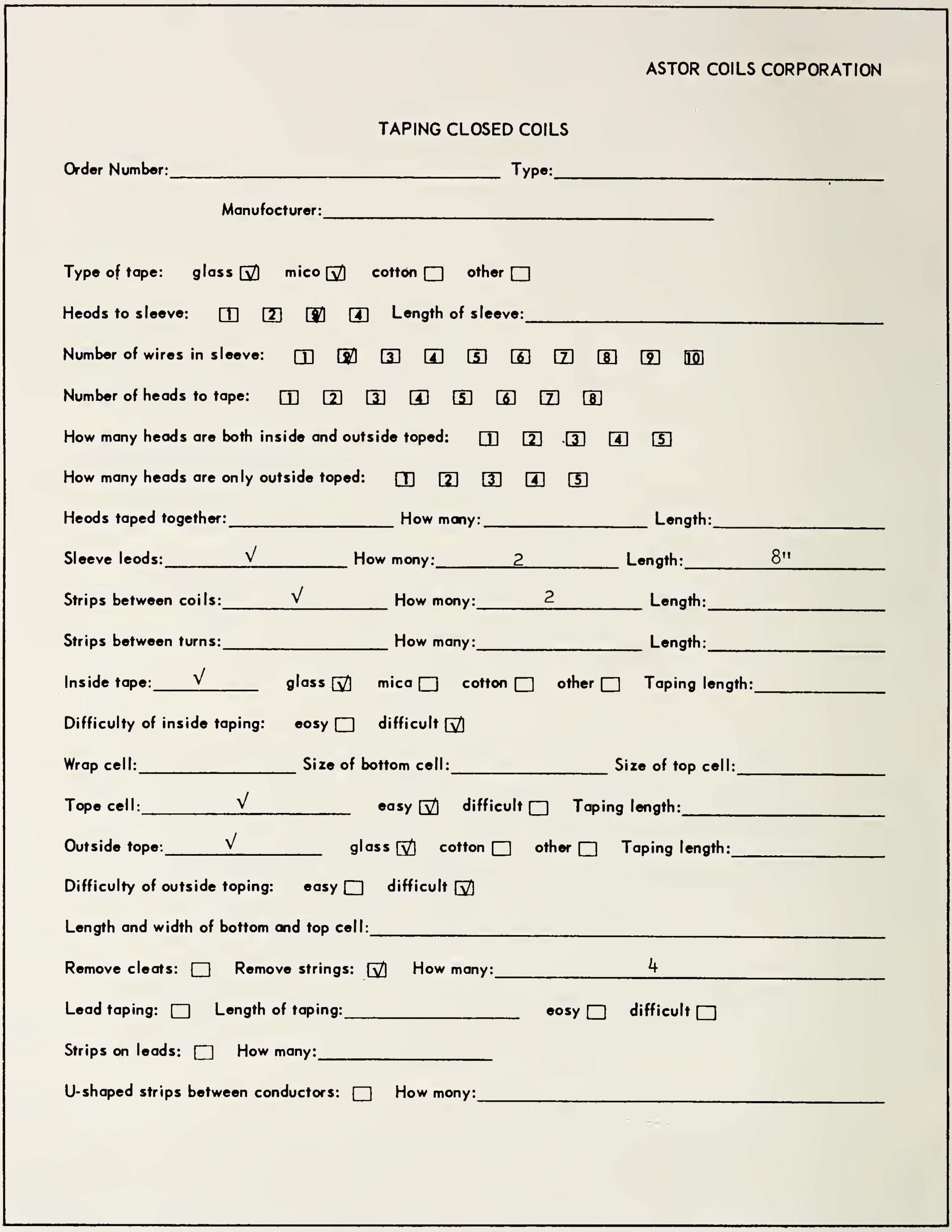
Although a few years previously some jobs had been subjected to time study, they were very few in number. And since time studies were needed on every job, the company decided to hire an outside expert to establish time standards.

The time study expert spent a considerable amount of time in the shop and in the office. His first task was to classify the various operations which had to be performed on a field, armature, or other type of coil. Since most coils had to go through practically the same operations, this presented no difficulty. A stator coil had to be processed in pretty much the same manner as an armature coil and field coils in the same manner as any other field coil, so further simplification was achieved by merely classifying coils either as armature or as field coils.

Once the production processes for different types of coils were established, the various motion elements commonly occurring in these jobs had to be established. This required many months of observation of various jobs in the production shop, but observation of the motion pattern and time study could both be accomplished at the same time. When all the information was gathered, the time study expert developed two basic decisional materials, namely, 1) time study data sheets and 2) elemental motion question sheets. The former contained all the motion time values; the latter asked questions about the nature of motions involved in the job, to be answered by the foremen in charge. Figures 1 and 2 and Table 1 in this order are the tools for the time study procedure.

The procedure for setting time standards, based on tables similar to Table 1, were very simple and required no specific training. First of all, when an order or inquiry came in, the method of processing had to be established. This was done by the foreman who looked at the blueprint sent along with the inquiry. He received Fig. 1 from the sales department along with the blueprint, sample coil, and other pertinent data (see Figs. 3 and 4). Since experience was the essence of process planning, it was easy to fill out the process sheet by merely affixing a check mark on the applicable operations (see Fig. 1).

Figure 1, when checked off, went back to the office where a folder was prepared on the job. The folder contained the various questionnaires relative to the various operations. Figure 2 indicates the type of questionnaire which



ASTOR COILS CORPORATION

TAPING CLOSED COILS

Order Number: Type:

Manufocturer:

Type of tape: glass ☑ mico ☑ cotton ☐ other ☐

Heods to sleeve: ☐1 ☐2 ☑3 ☐4 Length of sleeve:

Number of wires in sleeve: ☐1 ☑2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10

Number of heads to tape: ☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8

How many heads are both inside and outside toped: ☐1 ☐2 ☐3 ☐4 ☐5

How many heads are only outside toped: ☐1 ☐2 ☐3 ☐4 ☐5

Heods taped together: How many: Length:

Sleeve leods: √ How mony: 2 Length: 8"

Strips between coils: √ How mony: 2 Length:

Strips between turns: How many: Length:

Inside tape: √ glass ☑ mica ☐ cotton ☐ other ☐ Taping length:

Difficulty of inside taping: eosy ☐ difficult ☑

Wrap cell: Size of bottom cell: Size of top cell:

Tope cell: √ easy ☑ difficult ☐ Taping length:

Outside tope: √ glass ☑ cotton ☐ other ☐ Taping length:

Difficulty of outside toping: easy ☐ difficult ☑

Length and width of bottom and top cell:

Remove cleats: ☐ Remove strings: ☑ How many: 4

Lead taping: ☐ Length of taping: eosy ☐ difficult ☐

Strips on leads: ☐ How many:

U-shaped strips between conductors: ☐ How mony:

FIG. 2

went into the folder. The various department foremen dealing with the operation in question picked out of the folder only those sheets which concerned their own departments and on the basis of the blueprint or the sample coil answered the questions on the questionnaires, as illustrated in Fig. 2. When all operations were analyzed and the motion elements involved in the various operations were marked as in Fig. 2, the folder went back to the office.

TABLE 1

Standard Times for Cutting Armature Wire

Wire Length, Inches	Time for x Pieces of Wire*									
	1	2	3	4	5	6	7	8	9	10
10 20	.0302	.0604	.0906	.1208	.1512	.1814	.2116	.2418	.2720	.3025
30	.0423	.0846	.1269	.1692	.2117	.2540	.2963	.3386	.3809	.4235
40	.0544	.1088	.1632	.2196	.2722	.3266	.3810	.4354	.4898	.5445
50	.0665	.1330	.1995	.2660	.3327	.3992	.4657	.5322	.5987	.6655
60	.0786	.1472	.2258	.2944	.3932	.4718	.5504	.6290	.7076	.7865
70	.0907	.1814	.2721	.3628	.4537	.5444	.6351	.7258	.8165	.9075
80	.1028	.2056	.3084	.4112	.5142	.6170	.7198	.8226	.9254	1.0285
90	.1149	.2298	.3447	.4596	.5747	.6896	.8045	.9194	1.0343	1.1495
100	.1270	.2540	.3810	.5080	.6352	.7622	.8892	1.0162	1.1432	1.2705
110	.1331	.2662	.3993	.5324	.6655	.7986	.9317	1.0648	1.1979	1.3310
120	.1391	.2782	.4173	.5564	.6957	.8348	.9739	1.1130	1.2521	1.3915
130	.1452	.2904	.4356	.5808	.7260	.8712	1.0164	1.1616	1.3068	1.4520
140	.1512	.3024	.4536	.6048	.7560	.9072	1.0584	1.2096	1.3608	1.5125
150	.1573	.3146	.4719	.6292	.7865	.9438	1.1011	1.2584	1.4157	1.5730
160	.1633	.3266	.4899	.6532	.8165	.9798	1.1431	1.3964	1.4697	1.6335
170	.1694	.3388	.5082	.6776	.8470	1.0164	1.1858	1.3552	1.5246	1.6940
180	.1754	.3508	.5262	.7016	.8770	1.0524	1.2278	1.4032	1.5786	1.7545
190	.1815	.3630	.5445	.7260	.9075	1.0890	1.2705	1.4520	1.6335	1.8150
200	.1875	.3750	.5625	.7500	.9375	1.1250	1.3125	1.5000	1.6875	1.8755

* If +4 inches, take lower value; if +6 inches, take higher value.

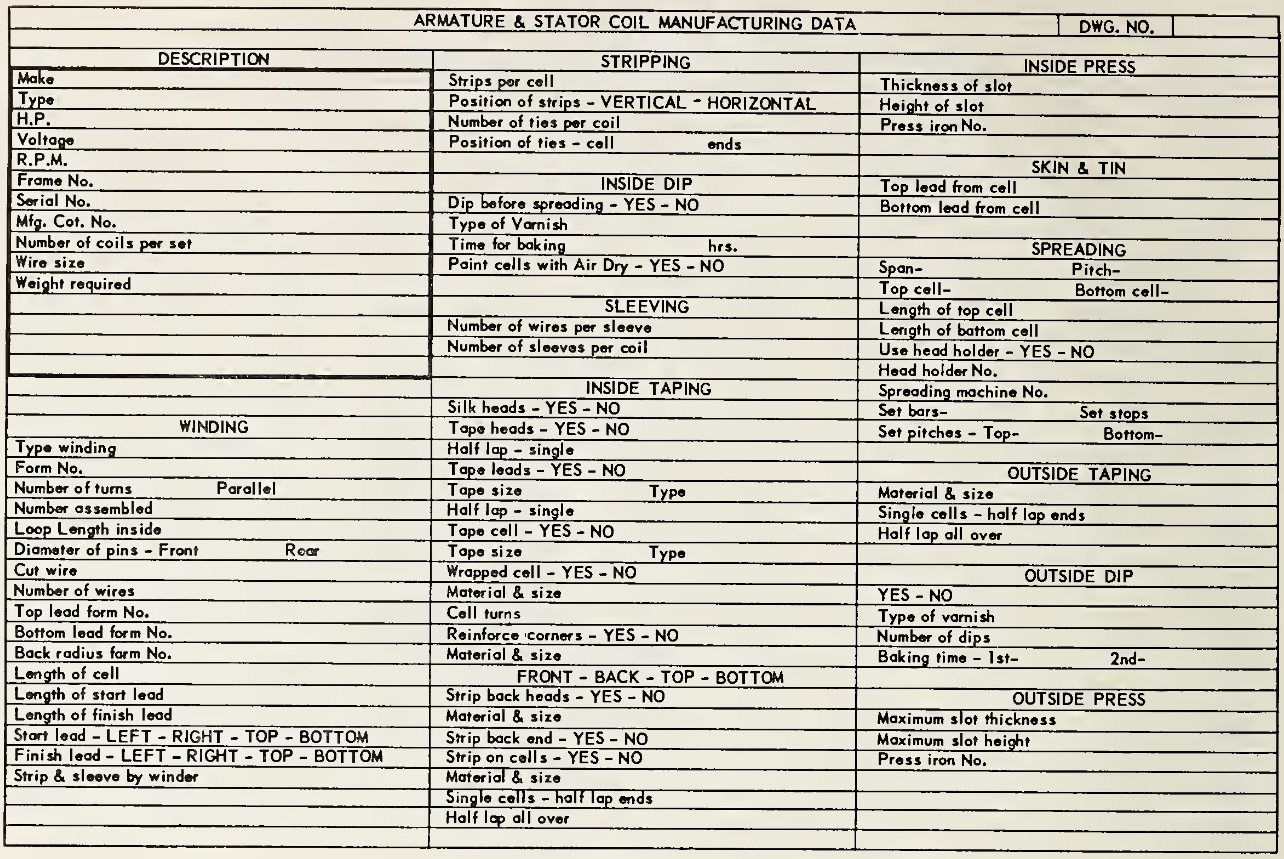
NOTE: The times include 10% of the original time for materials handling and 10% for allowances. If 40 wires must be cut and the reject factor is estimated, add an appropriate amount of time value to the original figure. Production of rejects also takes time. If reject is estimated to be 5%, we pick 40+2=42 pieces.

The office had the Time Study Data Book where the various operations and their individual motion elements were listed. Table 1 illustrates one sheet of the time study data sheet on the operation referred to as "cutting wire." To see how simple it is to prepare the time standard on the basis of information which the shop sends back to the office on these questionnaires, the following information is given on the cutting operation:

How many coils in a set?	30
How many wires per coil?	3
What is the reject factor?	10%
What is the length of wire?	41 inches

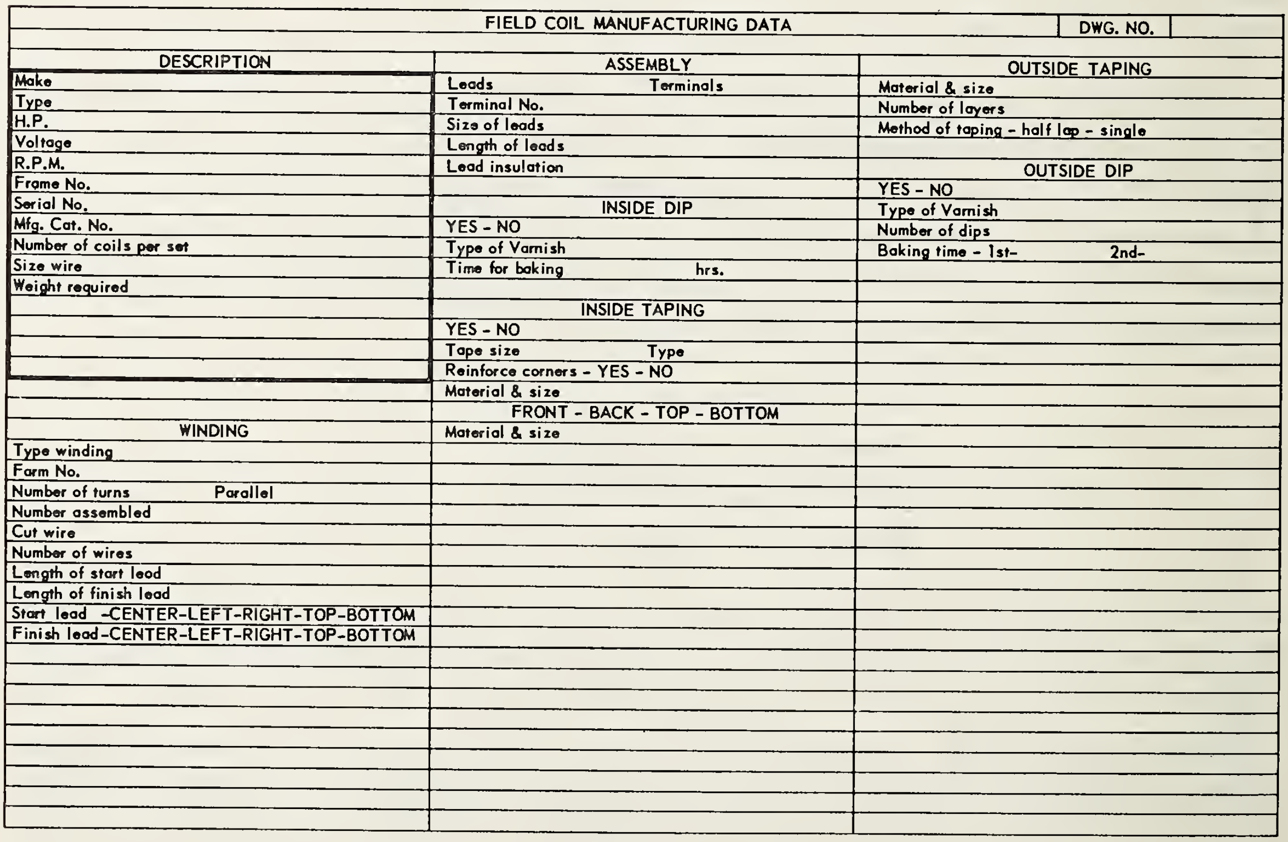
On the basis of the time study data sheet (Table 1) the time required on the operation "cutting wire" can easily be determined as follows: 30 coils × 3 wires = 90, total number of wires needed; 90 + 10% reject factor = 100 (rounded off) pieces of wire must be cut. We now go to the appropriate column (indicated in Table 1) and find the time required to cut 10 wires. Since we need not 10, but 100 wires, by multiplying that figure we get the time required to cut 100 wires: nearly 5½ minutes.

The same procedure is used until the time required to perform all operations on a set of coil is completed. The total time multiplied by the wage



ARMATURE & STATOR COIL MANUFACTURING DATA		DWG. NO.
DESCRIPTION	STRIPPING	INSIDE PRESS
Make	Strips per cell	Thickness of slot
Type	Position of strips - VERTICAL - HORIZONTAL	Height of slot
H.P.	Number of ties per coil	Press iron No.
Voltage	Position of ties - cell ends	
R.P.M.		SKIN & TIN
Frame No.	INSIDE DIP	Top lead from cell
Serial No.	Dip before spreading - YES - NO	Bottom lead from cell
Mfg. Cot. No.	Type of Varnish	
Number of coils per set	Time for baking hrs.	SPREADING
Wire size	Paint cells with Air Dry - YES - NO	Span- Pitch-
Weight required		Top cell- Bottom cell-
	SLEEVING	Length of top cell
	Number of wires per sleeve	Length of bottom cell
	Number of sleeves per coil	Use head holder - YES - NO
		Head holder No.
	INSIDE TAPING	Spreading machine No.
	Silk heads - YES - NO	Set bars- Set stops
WINDING	Tape heads - YES - NO	Set pitches - Top- Bottom-
Type winding	Half lap - single	
Form No.	Tape leads - YES - NO	OUTSIDE TAPING
Number of turns Parallel	Tape size Type	Material & size
Number assembled	Half lap - single	Single cells - half lap ends
Loop Length inside	Tape cell - YES - NO	Half lap all over
Diameter of pins - Front Rear	Tape size Type	
Cut wire	Wrapped cell - YES - NO	OUTSIDE DIP
Number of wires	Material & size	YES - NO
Top lead form No.	Cell turns	Type of varnish
Bottom lead form No.	Reinforce corners - YES - NO	Number of dips
Back radius form No.	Material & size	Baking time - 1st- 2nd-
Length of cell	FRONT - BACK - TOP - BOTTOM	
Length of start lead	Strip back heads - YES - NO	OUTSIDE PRESS
Length of finish lead	Material & size	Maximum slot thickness
Start lead - LEFT - RIGHT - TOP - BOTTOM	Strip back end - YES - NO	Maximum slot height
Finish lead - LEFT - RIGHT - TOP - BOTTOM	Strip on cells - YES - NO	Press iron No.
Strip & sleeve by winder	Material & size	
	Single cells - half lap ends	
	Half lap all over	

FIG. 3



FIELD COIL MANUFACTURING DATA		DWG. NO.
DESCRIPTION	ASSEMBLY	OUTSIDE TAPING
Make	Leads Terminals	Material & size
Type	Terminal No.	Number of layers
H.P.	Size of leads	Method of taping - half lap - single
Voltage	Length of leads	
R.P.M.	Lead insulation	OUTSIDE DIP
Frame No.		YES - NO
Serial No.	INSIDE DIP	Type of Varnish
Mfg. Cat. No.	YES - NO	Number of dips
Number of coils per set	Type of Varnish	Baking time - 1st- 2nd-
Size wire	Time for baking hrs.	
Weight required		
	INSIDE TAPING	
	YES - NO	
	Tape size Type	
	Reinforce corners - YES - NO	
	Material & size	
	FRONT - BACK - TOP - BOTTOM	
WINDING	Material & size	
Type winding		
Form No.		
Number of turns Parallel		
Number assembled		
Cut wire		
Number of wires		
Length of start lead		
Length of finish lead		
Start lead -CENTER-LEFT-RIGHT-TOP-BOTTOM		
Finish lead-CENTER-LEFT-RIGHT-TOP-BOTTOM		

FIG. 4

rate on that job classification gives the labor cost involved. The material cost is arrived at by discovering how many yards of wire is used. The overhead cost of the company was $2 on every $1 of labor cost. Hence, with the help of this system the company could determine in advance: 1) cost of making a set of coil and 2) performance times on every operation.

The consultant was present when the system was put into practice. The following description of certain situations which arose as a result of the system shows the general nature of production difficulties under such a system.

On December 15, 1961, an inquiry for a set of armature coils came in from the United States Steel Corporation's Irwin works for Type K8, originally a Westinghouse-manufactured armature coil, with a request for shipment within 3 days. The order requested price and delivery commitment. The order indicated that the list price on this coil was $28 (per x units). The cost calculation just described was completed in 10 minutes after receipt of the inquiry. Within 20 minutes the sales department returned the telephone call to the Irwin Works of United States Steel Corporation saying that in view of the 3-day shipment limit, Astor Coils Corporation was unable to complete x units of K8-type coils at $28 because to do so would call for overtime work which would raise the company's labor cost considerably beyond the normal costs of production. However, Astor Coils Corporation could promise shipment at $35 per x number of coils in 3 days. Otherwise, shipment could be made only on or about February 15, 1962.

The order was confirmed at $35 and, for the first time in recent history, the company completed a K8 order on a profitable basis. In the past the company had no idea how much it would cost to deliver a coil of this kind, but (because of the importance of the customer) would have accepted the order. Notice that the order was not refused, but a long delivery was given and overtime pay was used as an excuse for the higher cost; the labor cost alone would have been nearly as much as the list price of $28.

The employees at Astor Coils Corporation were paid on the basis of day rates, but on some jobs which were recurrent ones foremen had established piece rates based on professional guesses rather than time studies. Piece-rate jobs were fairly common in the armature coil department where repeat orders were frequent.

When the consultant had completed his project, the time study data sheets (a book of 150 pages with many sheets of information about certain motion elemental values) were put into use. They were, at first, used only to calculate costs to decide whether an order should be accepted or rejected. The production schedule was first consulted and, if time was available, the company accepted the job. If the backlog of orders was large and the schedules were tight, a low-cost job was accepted, but a high-cost order with low list price was refused.

Since this system worked and showed immediate results, as the interim report to the stockholders indicated, profits started to rise even though conditions in the steel industry continued to be depressed. The treasurer of the company suggested putting a piece-rate system of wage payment into operation. However, the president argued against this, saying that the little experience the company had had with the predetermined time study system did not yet indicate conclusively the validity of the time standards, though admittedly it gave pretty good information as to which jobs should be refused. He was in favor of using the information but only on an informal basis. Employees were to be told how many pieces they should deliver on their job, but it was up to the production foreman to make sure that the required output was accomplished. The piece rates which were in existence should not be changed. Records were to be kept to make a comparison 8 weeks later. These records of production (in total man-hours of labor) indicated the results in Table 2.

TABLE 2

Week	Allowed Time, Hours	Actual Time Spent on Job, Hours
Armature Coils; Piece-Rate Jobs		
1	400	405
2	600	602
3	350	349
4	707	702
5	513	511
6	289	286
7	657	655
8	777	778
Armature Coils; Day-Rate Jobs		
1	886	1,204
2	900	1,344
3	1,000	1,405
4	567	876
5	967	1,372
6	1,190	1,452
7	1,565	1,912
8	1,234	1,567
Field Coils; Day-Rate Jobs		
1	2,000	3,876
2	1,598	3,000
3	6,540	10,765
4	5,000	8,976
5	4,532	8,000
6	5,444	9,876
7	5,432	10,875
8	5,000	10,000

There is little doubt that the predetermined time standards were correct, actual tests versus calculated standards proved that beyond doubt. Furthermore, the piece-rate system on some armature coils indicated that the output based on 100% of normal performance was nearly always reached or surpassed. On the other hand, those jobs which were handled on a day-rate basis indicated only from 70 to 50% efficiency. The consultant and the president checked the output data and checked and rechecked everything to make certain that there was nothing wrong with the time study data sheets.

In June, 1962, production foremen were summoned to the office where they were told to push people constantly. This system did not work; for the report 8 weeks later indicated similar results. At this time, however, two winders were discharged from the field coil department because of incompetence. Although the labor union fought against the action, management proved to the business agent of the union that the two winders made a 4-hour job last 18 hours, at which time the union's protest was withdrawn.

The third 8-week test showed considerable improvement, possibly as a result of the firing of the two winders, and overall efficiency rose to about 80%.

Questions

1. What is your reaction to the time study system which was introduced unofficially?
2. What problems do you anticipate with this kind of time study system?
3. Identify the symptoms that this company was in real difficulty. What were the causes?
4. How would you attempt to eliminate the causes of low profitability existing in this company?
5. Do you detect signs of lack of proper production scheduling? If you answer this in the affirmative, indicate how you can tell and what factors support your answer.
6. What would you suggest Astor Coils Corporation should do in the area of production scheduling, time study, bidding for new contracts, cost estimating, etc. to get themselves out of this precarious situation?
7. What is your reaction to the consultant's approach to this company's time study problem?

chapter 8

Planning for Continuous Production

PLANNING FOR MASS PRODUCTION

Since the foundations for efficient mass production are laid at the time of plant construction, considerable attention must be paid to methods and facilities planning. The degree of accuracy to which every detail must be planned is largely dependent on the anticipated volume and approximate price at which the product must be produced if it is to appeal to the consuming public. That intensive planning pays for itself is due largely to the fact that the production plan (process design, methods, and plant layout design) will be formulated only once; thereafter, every item which the plant turns out will flow through a path common to all products. This common path—the production line—must be as perfect as circumstances permit.

However perfect the production plan when operations commence, continued improvement is necessary. In other words, the mass producer cannot sit complacently by and simply enjoy the fruits of process and methods planning, careful plant layout, and flow synchronization. In a dynamic business, the best methods of today become obsolete tomorrow. The plant built and tooled up for a given quantity becomes inefficient when the volume does not meet expectations, and price formation and other competitive challenges that mass producers encounter require a sustained effort to increase efficiency.

The key to productivity lies, on the one hand, in capital expenditures for the most modern facilities and, on the other hand, in a continuous effort to simplify work. Only the profitable company can accumulate the capital necessary to incorporate the latest technology, ingenuity, and ideas into its facilities. In mass-production industries, process planning, work simplification, equipment replacement, and modernization in general become a way of life.

Competitiveness in mass production is intimately related to the excellence of capital, but it does not rest entirely on facilities; to a similar extent, it rests on employment costs. Nevertheless, the greater the mechanization, the better use can be made of labor in the production process. The main effort in mass production must therefore be directed to integrating mechanical devices with labor skills, to making jobs suitable to human skills that are plentiful, and to adapting labor to improved mechanical and electronic devices. All this requires a great deal of methods planning. To make increasingly more complicated goods in the shortest possible time and with labor of limited skills, it is imperative to divide work into short assignments. A great deal of planning effort goes into making the work simple, and this is the important thing in mass production: to make men and machines serve each other.

Although short-run costs cannot be neglected, it is the potential long-run benefit that counts. The practical question is what can be reasonably expected from the new improvement and, specifically, whether the time and money invested in research and facilities can be recovered over the model year or expected production run.

It should be noted, however, that improvements, whether technical or nontechnical in nature, are always the result of human ingenuity. For that reason, no one should expect that process and methods study in mass production will drastically differ from that in intermittent production. Whether improvement is sought by studying plans still in preparation or work already in process, the mass producer and intermittent producer must make the same effort to simplify work and increase efficiency in general. Hence, the discussion of the preceding two chapters is valid whatever the type of production. The difference lies mainly in the depth and extent to which methods study is warranted.

THE CHARACTERISTICS OF MASS PRODUCTION

Mass production is an answer to low-cost production, but the stakes are high. As a practical matter, therefore, the following prerequisite conditions must prevail if mass production is to be contemplated:

1. Mass product for which there is mass consumption
2. Possibility of making the item by standardized production process
3. Applicability of mass-production techniques

Thus, when we speak of mass production, we must of necessity assume a sufficiently large demand and a relatively stable use of the item. We should note, however, that the use of standard processes and highly efficient production line techniques can create a mass demand and that, once there is mass consumption, mass production can sustain itself. In other words, mass production can create its own mass consumption.

The three basic characteristics of mass production may never be dealt with separately; they are interdependent factors and all three must be positive if mass production is to be profitable.

Continuous Versus Repetitive Mass Production

Regardless of the nature of the product—provided it qualifies as a mass product—the question that arises is whether it should be made continuously or repetitively, that is, in repeated intervals. In a sense, the answer is simple.

If the sale of the product is continuous, the chances are that it will pay to construct a plant for continuous operations. If demand is not continuous but is sufficiently large to justify mass-production techniques, the plant must operate in a repetitive fashion, that is, produce goods in batches in repeated intervals. The goods temporarily in surplus are stored and sales then draw on the inventory. In between runs, the plant is converted to secondary or multiple uses.

When the final assembly of a product is piecemeal, as when delivery of certain military long-run contracts is required in limited monthly installments, the parts-making and subassembly requirements are correspondingly in repetitive lots. Even when the final assembly of a product is continuous, the parts and components may be turned out in repetitive lots because the productivity of the parts-making facilities is greater than that of the final assembly. Another reason for repetitive-lot production might be that the processing time of parts is long. In either case, assembly draws on an inventory of parts. Also, it may be too complicated to balance the rate of output of subassembly and parts-making facilities with that of the final assembly. Thus, the latter will be continuous, the former repetitive.

One thing must be clear to the reader. The closer a company comes to continuous mass production, the smaller the amount of time that must be spent on production control. By the same token, the closer the company's operations resemble intermittent operations, the greater the production control effort must be to balance inequities in departmental work outputs and bring about a relatively smooth flow of production.

There is sense behind repetitive mass production, however. If demand is not continuous enough or if the continuous production is not justified on a cost basis, the plant or, at least, a part of the plant will be operated on a repetitive basis. Repetitive production is merely an attempt to make several goods with the same facilities and thereby avoid idle plant facilities over an extended period of time.

From the point of view of planning mass-production operations, whether repetitive or continuous, it is essential to consider all factors involved—product, process, method, volume, depth of tooling, plant layout, and flow pattern—in relationship to one another. In other words, no single one of the problems can be considered independently of all the others. Also, the solution worked out for any given problem might be weighted in relation to the answers to the other, interdependent problems. Finally, all the solutions must be reduced to a common denominator and checked against all other considerations before the plan is complete. Volume considerations will play an important role in determining the sophistication of tooling and the product design, which, in turn, will determine the nature of production, the processes and the methods, the balance between operations and machine groups, and the selection of equipment. More will be said about this later, but at this point it should be clear that no matter whether mass production is to be continuous or repetitive, plant facilities must be planned and designed with considerably greater care than they would be if the production were intermittent.

It is often asked which plants should operate under the continuous system and which under the repetitive one. A clear-cut answer is difficult because many companies can effectively operate under both systems at the same time. The operation of the assembly departments may be continuous, and the operation of the subassembly and component-manufacturing departments may be repetitive. Although most process industries would qualify as mass production, few would fully qualify as continuous mass producers. When standard items such as light bulbs, guns, cement, beer, sugar, meat, or dairy products flow through the plant facilities in a predetermined fashion, it is usually possible to operate continuously; but when the facilities must be converted to secondary uses either because customer desires vary substantially or because demand is not continuous enough, the plant is bound to operate on a repetitive basis.

PLANNING FOR OPERATIONS AND UNIT COSTS

In deciding on the technical perfection which is warranted by given sales conditions, the planner bases his decisions on unit costs rather than on total costs. The difference will be explained later. At this point we merely note that the unit cost is obtained by dividing the total cost by the number of units.

To use unit cost as the basis of decision, therefore, it is essential to know the level of output. The plant in mass production is planned for a certain anticipated volume. Although the short-run volume is important, the long-run volume is the decisive element. Sophistication in tooling depends on whether the cost of the tool or the equipment can be legitimately depreciated over the expected sales volume.

The sales forecast is usually the information upon which decision is based. Some companies defy the sales forecast and make a conservative estimate to avoid the possibility of overtooling. In that event a "standard volume" is assumed and a plant based on that volume will be built. The sales organization is then more or less committed to sell that volume. If the figure turns out to be much too conservative, the company has operated with a higher unit cost than would have been necessary. Generally speaking, the more goods that can be sold, the more capital that can be invested in tools and the more time that can be devoted to process and methods study. By the same token, the lower the output, the less the expenditure in time and effort and tools that is warranted. If the plant undertools or operates with imperfect methods and processes, the labor cost will be higher than is desirable. On the other hand, if a plant overtools and overplans, the chances are that the labor costs will be low, but the unit cost will still be high because of unduly high capital costs.

PLANT LAYOUT

After determining how much mechanization and work simplification is warranted by the volume considerations, the question that arises is whether the plant should be laid out for a single product or for a limited amount of product mix. The primary objective is to so arrange plant facilities that progression from unworked material to shipped product is uninterrupted without backtracking. While the forward movement of materials is usually assured in repetitive production also, the flow is not usually so perfect that a conveyor system can be installed to keep the flow of production uniform. Here imbalance and gaps in production must be evened out by temporary, scheduled storage of accumulated materials.

The typical job shop tends to group machines of like operational characteristics into departments. Although the position of individual machines on the plant floor is not strictly designated, the departments are arranged in some suitable and logical fashion. Backtracking is necessary because, as certain equipment is needed, the product must move to the department where the equipment is located. The route that each product takes is different, and none of the orders is large enough to justify the use of a given part of plant capacity in any fixed sequence. The situation differs in mass production.

In large-scale operations the product moves to the machines (not to departments) and the machines are, in contrast to the process layout system, located along the production line in order of their need rather than grouped according to likeness. Thus, a grinder, a welder, and a milling machine may be neighbors. Distances between machines, and thus the distance the product moves, are kept at a minimum.

As said before, this kind of arrangement is warranted only if a single standard product can be produced in large volume to keep the production capacity utilized most of the time. If demand does not warrant such a plant arrangement, then two, three, or more products must make use of the same line. It is apparent that there will then be complications that must be worked out. The fact is that no two products will have exactly the same process, and it will be up to the various engineering groups and the production control department to make such a line move despite a probable imbalance.

Machinery and Plant Layout

As opposed to the multipurpose machinery found in an intermittent job shop, high-speed special-purpose machinery characterizes continuous and also, to some extent, repetitive production. These machines are designed to perform highly specialized operations. While the advantages in terms of speed and accuracy are great, such equipment is subject to fast obsolescence in a technologically progressive industrial society. Obsolescence can also result from a sudden change of consumer desires. Nevertheless, the use of special-purpose machines results in quite substantial savings in that the machines permit both the use of relatively unskilled or semiskilled operators and the combination of several operations into one. Thus, special-purpose machinery will not only increase speed but also tend to reduce the number of work stations required. Since several operations which would be necessary if standard machines were used may now be performed simultaneously by the special equipment, the production cycle, the performance time, and many other production elements that are usually reflected in cost can be reduced to a minimum.

Unless the production line can be kept in continuous use during a reasonable portion of the time (for what is reasonable, see explanation of the break-even concept on page 335), its construction is not warranted. When operating at, say, only 50% of normal one-shift capacity, a production line can result in higher unit costs than its less efficient counterpart would if used for multiple purposes which would keep it busy 90% of the time. Mass production's low-cost operations result from the process and methods planning that breaks different tasks up into small segments. Not only are the operations simplified, but a precisely planned motion pattern may permit performance within a considerably shorter time than would be possible under the process layout system. The fact that the various operations may be broken up into equal time-performance units is of further significance in that it is possible to combine mechanical devices, such as a constantly moving conveyor, with human performance. Thus, the otherwise unpredictable human performance can be placed under mechanical control.

As already indicated, production line efficiency can backfire unless the facilities are in constant use. To avoid the possibility of sustained idleness, repetitive or intermittent production may be selected. The equipment can then be used for other purposes if a slackening demand prevents a high degree of capacity utilization for the primary purpose. Repetitive production will employ unit-type equipment, which may be nearly as efficient as special-purpose equipment. The only difference is that it is so designed that it can perform operations on different-sized products and can be adjusted to handle different dimensions. It is not as versatile as the general-purpose machine used in job shop production, however. The advantage of repetitive mass production, of course, is that idleness of facilities can be kept at a low level. But because of differences in the product lines, it may become quite complicated to plan the facilities in repetitive production. In a sense, a convertible production line must be built, but to make production flow as continuous as it would be if a single product line were to be produced can be a nearly insurmountable task.

We may have given the impression that the machines we speak of are already arranged on the plant floor. Nothing can be further from the truth. We speak here of planning activities, and planning is done on paper. We shuffle machines, calculate operation times, and synchronize the movement of the line with the conveyor movements on paper only. That is the beauty of planning. We can create reality on paper, and we can make important decisions even before a single machine is purchased or moved in the physical sense.

Having clarified that in the planning stage we merely do things on paper, we must also note that there is a great deal of difference between a theoretical production line and one that will actually operate. Nevertheless, a good theory must lead to good practice. And if the calculations and everything else that goes into planning of the physical facilities are theoretically correct, the chances are that they will work out in practice. Any possible bugs are eliminated during a pilot run. Generally speaking, the product will move forward either in a straight line or in an odd-angle fashion.

To make sure that each work station is able to absorb the output of the preceding station, the planner takes into consideration the manufacturer's statement about the output capacity. The arrangement of the motions and the workplace layout will, by synthetic time study procedure, give adequate information on the time requirement at each work station so that output and time requirements can be both balanced and synchronized. Unless the various machines can keep up with one another, flow cannot be attained. If production flow is at a rate of 200 units and one machine is inadequate to turn out those 200 units but can make 100, then there is a need for two machines at that work station. Balancing operations may take several different forms: 1) synchronization in the time unit, 2) balance through output capacity, that is, using two or three machines at one work station if individual machine output is inadequate to attain required output quantity per work station, and 3) balance through temporary storage and staggering of production by the production schedule. The third method requires building of banks of materials by working overtime at certain work stations, running second shifts at certain key machines, or temporarily shutting down machines which have more than required output capacity. This does not mean, of course, that the machine stands idle; it may merely be assigned to the production of something else on a job shop basis.

Minor imbalances may still be present even though the overall flow is pretty much even. They will be eliminated through careful methods engineering and work simplification. Adding a few clever clamps or holding devices can eliminate holding and can shave a few seconds from the operation time. Many little changes of this kind can add up to a half a minute, which may be just the amount that has to be saved.

From the point of view of production planning, the importance of a preset production rate cannot be underestimated. Planning is relatively simple as far as the line is concerned; but, of course, how to keep the line moving and how to correlate that movement with a supply of needed materials is something else again. This goes beyond our present interest, however, and more will be said about production planning and control at a later place.

PRODUCTION DESIGN

To emphasize the close relation between design and mass production, we can state that, in order to have the best production process, design must conform to production rather than consumer requirements. The consumer's interest is by no means neglected, of course, but a great deal of emphasis must be put on the production aspects of design and particularly on producibility. The best possible design technically would be worthless if it could not be adapted to mass-production techniques.

To be specific, design engineers must always bear in mind that any product intended for a broad market must be priced to fit the consumer's pocketbook. The design must be functionally sound, yet all design considerations, including beauty and styling, must be subordinated to the practical consideration of producibility through highly efficient methods. Of course, none of the design considerations can be neglected to the exclusion of all the others.

Because of the importance of production design in mass-production industries, and particularly so in durable goods, the various engineering groups must work in cooperation with one another. Design engineers constantly ask advice of the process engineers. In a sense, the latter are the ones who can more or less tell in advance whether a given design can be produced at low cost and with methods capable of attaining desired ends. Usually the process engineers have the authority to determine methods and must, by that circumstance, have an important voice in the design. Obviously, a request for design change during the development stage of design work is preferable to a later change that might be costly and would require junking valuable tools. Figure 8-1 illustrates a single fixture that may be utilized in place of twelve fixtures resulting in a considerable saving in initial cost. Although important and necessary changes may still be considered at a later time, the expenses associated with last-minute changes will be carefully scrutinized. Often as a direct result of an alteration in the product, a machine and a work station must be redesigned and replanned. For that reason, management of firms engaged in mass production usually places responsibility for design in the hands of production experts rather than the design groups. This can, however, vary from plant to plant.

Since design is closely related to production engineering, the intimate relation which exists between design and output levels must also be pointed out. The greater the volume, the greater the investment in tools and special equipment that is warranted and, consequently, the greater the time that can be devoted to equipment and tool design. Certain designs lend themselves to better production methods, that is, higher speed. The output level which warrants high-speed equipment must be carefully determined. Design improvements will precipitate further improvements in machine design or tooling also. All this work on the part of the designers costs a great deal of time and money that must, under any circumstances, be recovered to make the new design economically feasible. The design must justify the expense of its tooling. To see whether the introduction of an improvement in design pays for itself in the sense that all tooling expenses are recovered, the surplus output over output requirements of the initial design must be ascertained. This can be expressed mathematically:

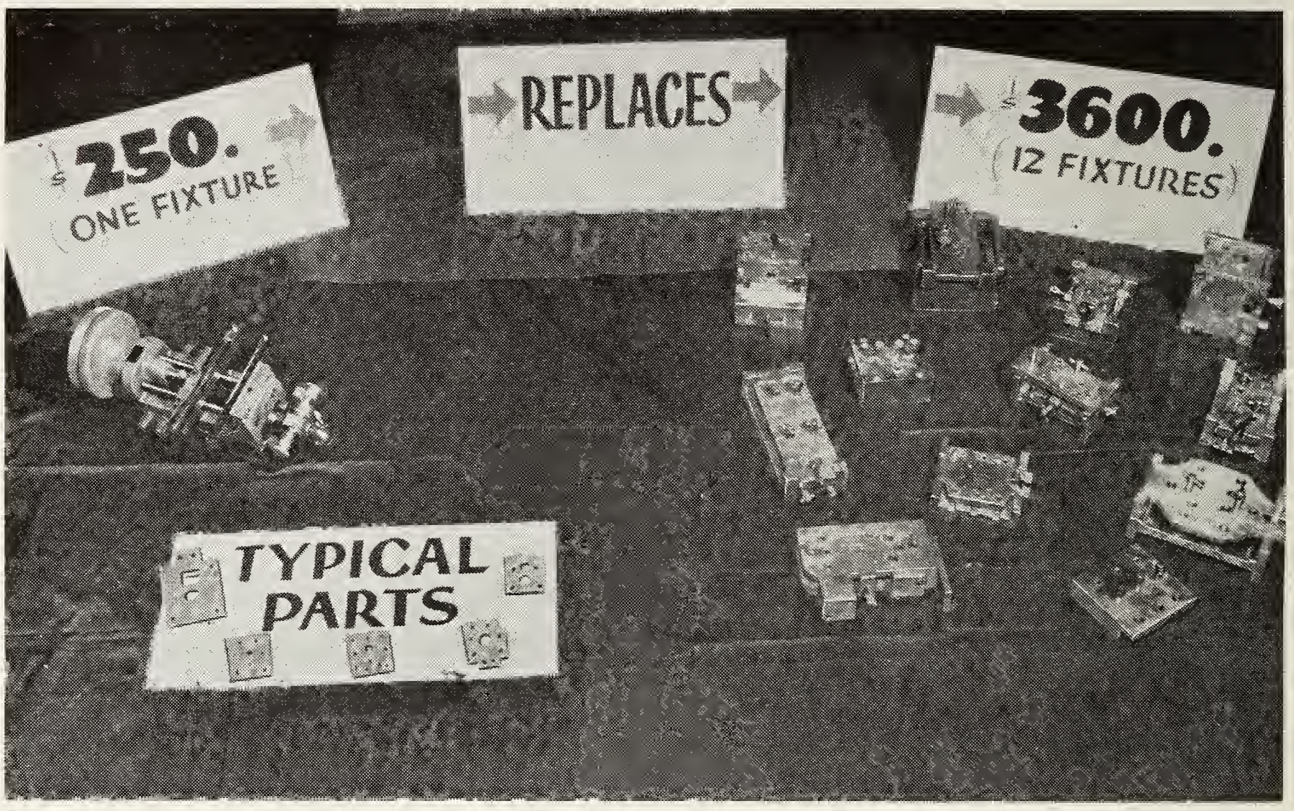


FIG. 8-1. Example of improved production design. (Courtesy of Brown and Sharp Manufacturing Co.)

$$x=\frac{a-b}{c-d}$$

where x = added production volume (in thousands) necessary to make the alternative design pay for itself in spite of new tool-up costs;
a = tool-up costs (including some other costs, such as maintenance per year related to it) necessitated by alternative design;
b = tool-up cost of the original design (undepreciated portion);
c = cost of production per thousand (material, labor, overhead) of the original design;
d = the cost of production per thousand (material, labor, overhead) under the alternative design.

Assuming that

$$x = \frac{\$1000 - \$200}{\$50 - \$40} = 80{,}000 \text{ pieces}$$

the conclusion is that 80,000 additional pieces would warrant introduction of an alternative design on the ground of long-run savings to be derived from the more effective method. All these considerations are admittedly interlaced and deserve simultaneous attention. After the original design is settled, too many further design changes can lead to rising costs in a sense that the recovery of tooling costs becomes almost impossible. On the other hand, scrapping a perfectly good tool if a better design is discovered sometime after the start of operations may be beneficial if the new design promises long-run saving in excess of its introduction costs.

OPERATIONS PLANNING

It must be apparent by now that planning work in mass production shops starts considerably earlier than in job shops. During the planning, every detail is worked out so that operations can start without snags and delays. The route, so important to orderly production in job shops, is built into the production line. While scheduling is still necessary, it is no longer done operation by operation, because the production line as a whole is, in a sense, one big machine. Hence, the work load is scheduled on the basis of the output capacity of the whole production line. It is important to remember, however, that this is possible only because careful preparatory work is done by the various planning groups.

The linking of hundreds of machines together so perfectly that they all function as one big piece of equipment represents a total planning effort that is shared by a large number of technical men. The important difference in planning for mass production is the greater scrutiny and precision with which it must be performed, rather than in any fundamental departure from the process and methods planning work described in Chapters 6 and 7.

There are bills of materials as well as process sheets in continuous production, but they serve primarily as the basis of plant layout and time study work (see Fig. 8-2). The process will very likely be studied by methods men to see whether a still better method can be devised. But since the plant layout itself will determine even the nature of the production control work, industrial engineers are the key to continuous production. They are the ones who create a perfectly functioning chain of machines and connect the work stations so carefully that each station has an output equal to that of the next.

It must be apparent that the need for accuracy in time study in continuous operation is considerably greater than in repetitive operation, while a good approximation is usually sufficient for a job shop. Unless the work load of each work station is equal to that of the others or is at least so balanced that

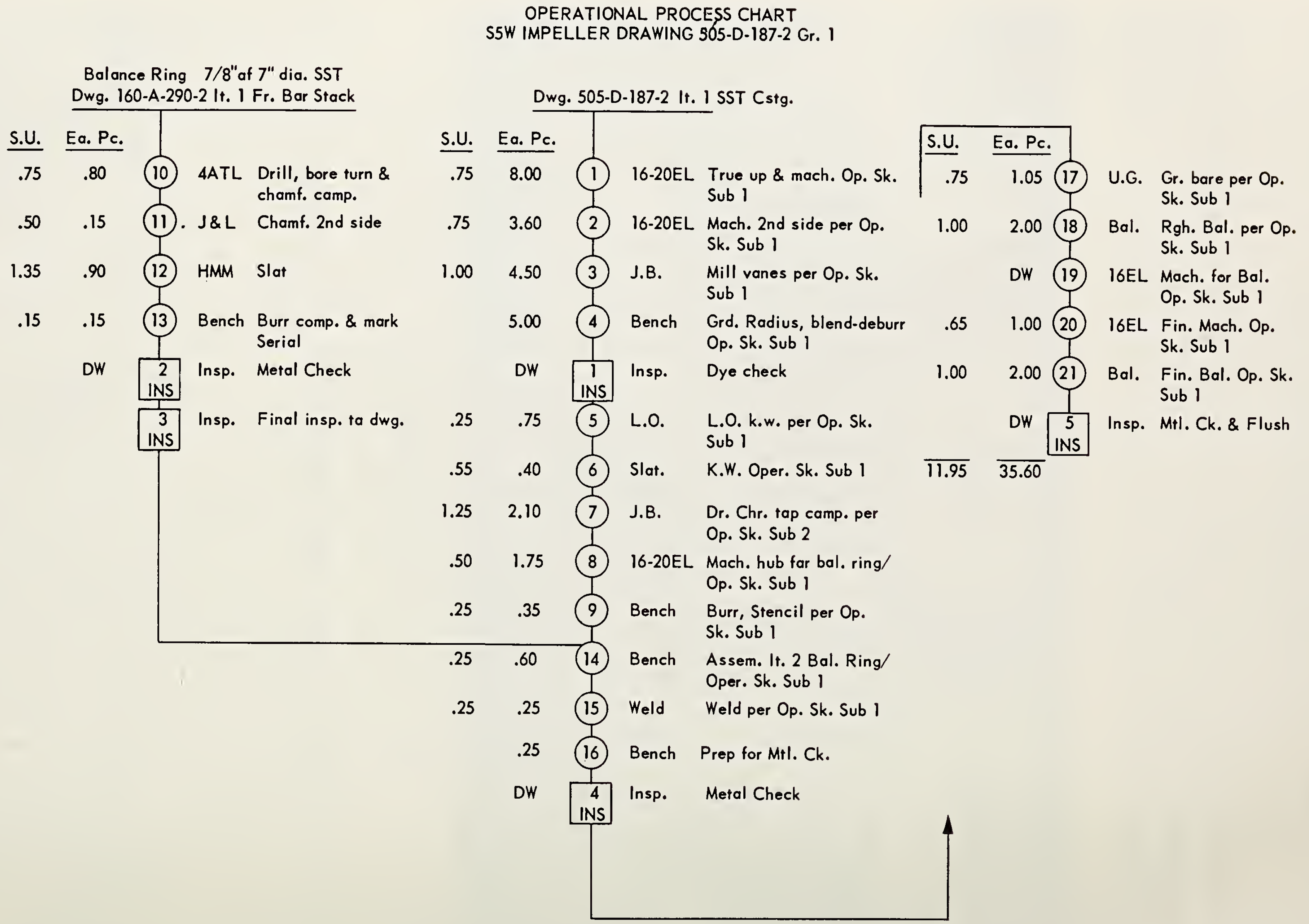

OPERATIONAL PROCESS CHART
S5W IMPELLER DRAWING 505-D-187-2 Gr. 1
Balance Ring 7/8"af 7" dia. SST
Dwg. 160-A-290-2 It. 1 Fr. Bar Stack
S.U. Ea. Pc.
.75 .80 10 4ATL Drill, bore turn & chamf. camp.
.50 .15 11 J&L Chamf. 2nd side
1.35 .90 12 HMM Slat
.15 .15 13 Bench Burr comp. & mark Serial
DW 2 INS Insp. Metal Check
3 INS Insp. Final insp. ta dwg.
Dwg. 505-D-187-2 It. 1 SST Cstg.
S.U. Ea. Pc.
.75 8.00 1 16-20EL True up & mach. Op. Sk. Sub 1
.75 3.60 2 16-20EL Mach. 2nd side per Op. Sk. Sub 1
1.00 4.50 3 J.B. Mill vanes per Op. Sk. Sub 1
5.00 4 Bench Grd. Radius, blend-deburr Op. Sk. Sub 1
DW 1 INS Insp. Dye check
.25 .75 5 L.O. L.O. k.w. per Op. Sk. Sub 1
.55 .40 6 Slat. K.W. Oper. Sk. Sub 1
1.25 2.10 7 J.B. Dr. Chr. tap camp. per Op. Sk. Sub 2
.50 1.75 8 16-20EL Mach. hub far bal. ring/ Op. Sk. Sub 1
.25 .35 9 Bench Burr, Stencil per Op. Sk. Sub 1
.25 .60 14 Bench Assem. It. 2 Bal. Ring/ Oper. Sk. Sub 1
.25 .25 15 Weld Weld per Op. Sk. Sub 1
.25 16 Bench Prep for Mtl. Ck.
DW 4 INS Insp. Metal Check
S.U. Ea. Pc.
.75 1.05 17 U.G. Gr. bare per Op. Sk. Sub 1
1.00 2.00 18 Bal. Rgh. Bal. per Op. Sk. Sub 1
DW 19 16EL Mach. for Bal. Op. Sk. Sub 1
.65 1.00 20 16EL Fin. Mach. Op. Sk. Sub 1
1.00 2.00 21 Bal. Fin. Bal. Op. Sk. Sub 1
DW 5 INS Insp. Mtl. Ck. & Flush
11.95 35.60

FIG. 8-2

it permits a continuity of production flow, the plant layout is not suitable for continuous operation. Hence, the plant layout and time study men cooperate carefully so that the production line is eventually perfectly synchronized.

CAPACITY OF THE PRODUCTION LINE

Plant capacity is a matter of knowing how many units, whether gallons, tons, or pieces, the production line can turn out per unit of time. This capacity tends to be gaged to the demand conditions; management tends to make the size of the plant commensurate with overall demand. Any serious error on the part of the planners in appraising the size of the market can lead to overcapacity, with adverse financial consequences. Therefore, the first step in planning the output capacity is a long-range sales forecast. Of course, what "long-range" will mean depends largely on the nature of the product and its production process. Long-range demand for a product with a yearly model change means 1 year, but long-range demand for a bottled product might mean 10 to 30 years. Thus, in order to determine the plant capacity, the demand conditions relative to the period for which the plant is being built must be appraised first of all.

The second step in establishing the capacity of a continuous-production plant is related to the yearly average demand. If the yearly average demand per one-shift operation is estimated at 115,000 units, then the monthly capacity is 9600 units and the daily capacity, assuming 20 workdays a month, is 480 units. Thus both cost considerations and the design of the production process must be based on this 480 units a day capacity. The production line must accordingly turn out one unit per minute. The determination of how many machines must be acquired to get this output from every work station is the primary task of process and methods planners. They have to plan things in such a manner that the production line as a whole is capable of invariably turning out 480 units per day.

Since equipment selection is purely a technical function, no attempt is made to explain it here. It is obvious, however, that equipment is looked upon with capacity needs in mind. Under the assumption of the preceding paragraph, a machine that is unable to produce 480 units per day must often be redesigned in order to build its capacity up to that output level. If a piece of equipment is capable of turning out only 160 units per day, it is necessary to have three pieces of that equipment to turn out the required 480 units. In that case the plant layout people must also design a system whereby the product goes from one machine to the next so that the next work station is invariably supplied with an adequate amount of material to keep the line moving. The starting of the machines must be so staggered that, after floating the production line—that is, loading each work station with work—production can flow uninterruptedly. More will be said later about production line synchronization and balancing.

THE BREAK-EVEN CHART

As previously indicated, a wide range of cost considerations is necessary to sound decision making in continuous production. In evaluating the various factors such as output, revenue, and variable and fixed costs in determining the desirability of a certain size plant, a chart might be used. This is the break-even chart, which will indicate with some degree of accuracy the size of the plant commensurate with sales requirements at various prices.

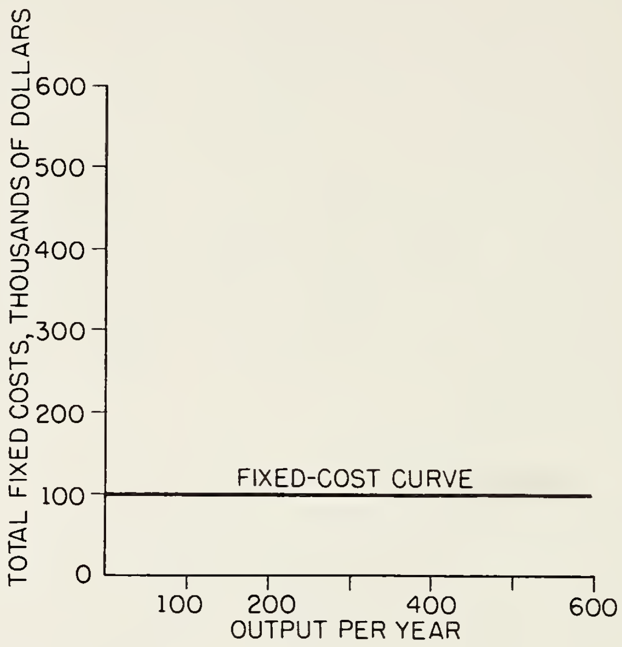


FIG. 8-3

Although large-scale production tends to reduce the unit costs, the behavior of the capital costs differs markedly from the behavior of labor and material costs. The difference is due to the fact that the capital costs are relatively fixed whereas the material and labor costs may vary with the volume of output.

Capital costs are fixed because of the indivisibility of the capital invested in the plant. In other words, the plant will not operate unless every part of the physical facilities is built at once. Nevertheless, the machine will last for years and operate over an extended period of time. Thus, all capital costs are spent at the time the plant is built, yet they will be recovered only piecemeal over the years. According to the Internal Revenue Code, only a yearly apportionment of the total capital cost is counted as cost. If we assume a straight-line depreciation, the yearly cost, based on the total capital investment, remains fixed in the sense that it becomes independent of the volume of output achieved in the plant. If a million dollar plant wears out in 10 years and its value, based on the straight-line method, is depreciated at 10% per year, the fixed cost is \$100,000 per year. This \$100,000 must be divided among the yearly output units to get the capital cost per unit. It is apparent from Fig. 8-3 that the yearly capital cost remains the same regardless of the output unit; that is why it is called fixed cost. Thus, low output in any given year would cause per unit capital cost to be high. Before a plant is built, it is important that the company have a fairly accurate idea about the nature of sales, because the sales volume will determine the capital cost per unit of output—one of the most important parts of the overhead costs. Product pricing is often dependent on the distribution of the yearly fixed costs. Of course, some other costs, such as executive salaries, heat, and light, behave similarly to capital costs. For sake of simplicity, no mention is made of them here, although they must enter into the considerations.

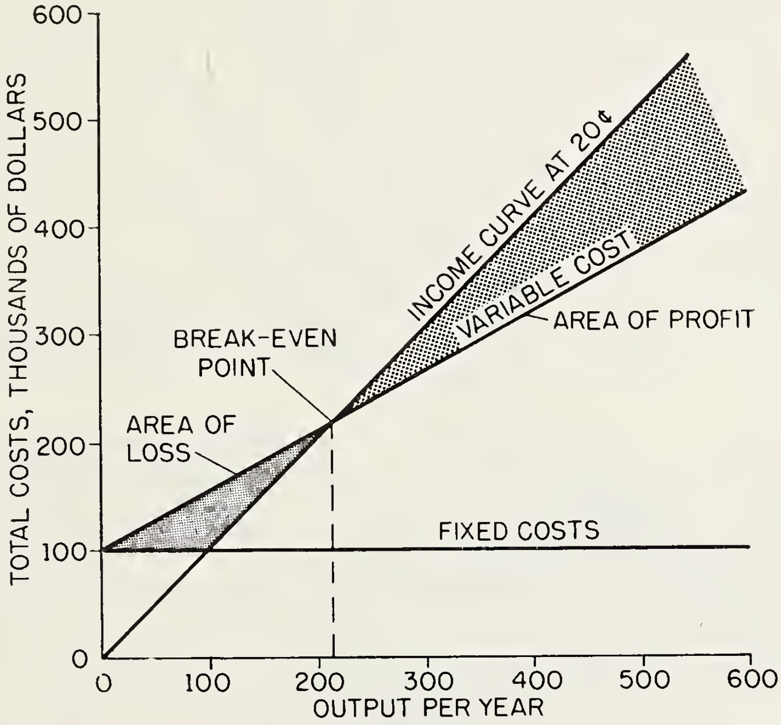


Fig. 8-4

In view of the fact that demand means something only in terms of revenue, the latter must now be contrasted with the fixed and variable costs (labor and material) associated with production. Assuming a constant price[1] of 20 cents per unit, the revenue line will intercept the fixed cost curve as indicated in Fig. 8-4. Now if we further assume that the cost of labor and material rises pretty much in proportion with the output (which again is not quite so), then we create a relation between the various cost elements in form of a break-even chart capable of indicating the operating costs of a given plant at different levels of capacity utilization.

The planner, by means of the break-even chart, relates the various cost elements with expected output and with estimated capital expenditures. The cost of capital equipment can be determined by making inquiries of machine builders; labor cost can be estimated on the basis of labor skill and the number of workers the production line will require, in addition to the estimated behavior of the "learning curve"[2] as the volume of production grows. Material costs depend largely on volume of the expected purchase, which can be determined well in advance so that prospective suppliers can quote their prices on that basis. The possible selling price of the product can be estimated by competitive prices or, if the item is entirely new, by making some reasonable assumptions.

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[1] Ordinarily, the assumption of a constant price is merely a theoretical oversimplification, because products must often be priced in accordance with inventory position.

The break-even chart in Fig. 8-4 assumes a price of 20 cents per unit, but to be more realistic several possible prices can be used, as indicated in Fig. 8-5. Particularly in durable goods, price concessions can seriously influence the dollar volume of sales. Conversely, raising prices will tend to influence demand. In mass production, it is essential to ascertain the nature of demand for the product before building the plant. How this can be done is another problem. Based on three different prices, on the yearly capital depreciation cost, and on variable costs, the output sales potential can be appraised. These possibilities are important, because the break-even point will vary with price ranges. On our chart, Fig. 8-5, at price 1, the break-even point is at *b,* at price 2 it is at *a,* and at price 3 it is at *c,* meaning that a larger yearly output is needed to recover costs if revenue is at the intersection *c*.

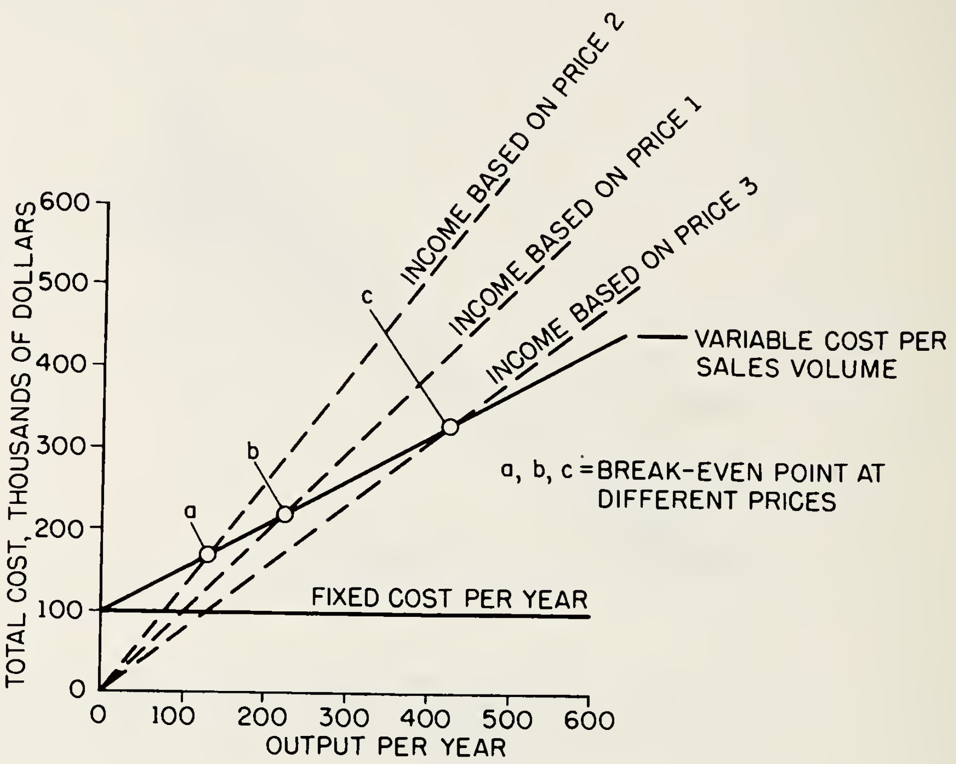

FIG. 8-5

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[2] The learning curve will indicate the changes in the number of hours required to turn out a given output. Increasing volumes of output will in certain industries require not a corresponding number of hours but somewhat less. Thus, labor cost per unit of output will show a falling tendency as output increases.

SIGNIFICANCE OF THE BREAK-EVEN POINT

The break-even point is of great concern to the continuous producer. If operation is to be profitable, it is mandatory that continuous use be made of production line capacity, and particularly that the yearly output volume will exceed the break-even point. The more units that can be sold above the break-even output level, the greater the profitability. It is advisable that the production capacity of the plant be set at the average monthly demand for the product. This does not preclude gyrations in demand, but the more nearly the firm can estimate its sales volume and gage its production to it, the more profitable its production becomes. This will eventually permit a continuous flow of production and a capacity utilization of equipment. Of course, the assumption is made here that a production line is planned with the capability of neither more nor less than its share of the market. By looking at the break-even points at assumed income levels and by extending lines from the break-even points down to the output line (the horizontal line), the minimum quantity which must be produced per year to recover the costs of production is established, and hence the minimum output capacity of the plant is established. The sales forecasting and one's normal share of the market are invaluable aids in reaching this kind of managerial decision.

PLANT-LIFE BREAK-EVEN POINT

In determining the capacity of the production line, it is essential to know not so much the short-run costs and revenues as the long-run costs and revenues. Many decisions will turn out to be wrong if they are based on short-run costs rather than on the more important long-run costs. Thus, the planner should take into consideration the average labor cost over the years[3] (including the possible wage rate changes through contract negotiations), raw material price rises, etc. He should also consider changes in revenue. If the price at the outset is higher than the price that will probably be obtainable toward the end of the life of the product, it is essential to set an average revenue for the life of the product. For example, nylon and the various other synthetics commanded a considerably higher price during their earlier years of existence than they command today.

SETTING UP THE PRODUCTION LINE

The production line is developed on the basis of capacity considerations. Barring unduly burdensome overspecialization, the fewer the motions assigned to a work station, the greater the operational efficiency will be. It is up to the process planner, aided by the plant layout and time study men, to determine

[3] For a more detailed discussion on this subject see L. J. Rago, "Rationalization Means Reduction of Costs," *Machine Tool Engineering and Production News,* vol. 94, March, 1961.

the total number of operations into which the production line must be divided to meet output capacity requirements. The selection of equipment or equipment design is the next step; this must be followed by work station balancing and synchronization.

MECHANICS OF PLANT LAYOUT

The plant layout is sketched on paper. Templets, miniature machines, or other devices such as three-dimensional models can be used to depict the possible appearance of the production line. A process flow chart (see Chapter 7) may precede the actual arrangement of equipment on the available floor space. Actually, when new plants are laid out, it is customary to work out the layout of the plant in minute detail and only then commission an architect to build a structure around it. In other words, the plant layout should be planned first and building plans should follow.

After the physical arrangement of the machinery on the plant floor, pilot runs will precede actual plant operations. The pilot run operates under approximately normal operating conditions. As a rule, a smooth flow of production will still have to be worked out through further analysis of the production line. Direct time studies must be made; they will give actual time requirements on every work station as opposed to those calculated for use in planning. Each operation is certain to take a slightly different length of time than planned. What the plant layout engineers must do is to perfect the flow, although at this time there is already a pretty good balance between work stations of the line. With the help of predetermined time standards and on the basis of statements from machine builders, the approximate output capacity of the various machines used in the production line was known. Thus, the line at this stage of planning needs only to be perfected.

CREATING THE PRODUCTION FLOW

The diagram in Fig. 8-6 illustrates the possible production flow which is worked out on the planning board. Since production will be controlled by the slowest operation, it is essential that slow operation stations be speeded up and that operations requiring less time than the predetermined rate of flow be assigned more work. If production is designed to flow in such a manner that a TV set comes off the line every 3 minutes, each operation must be

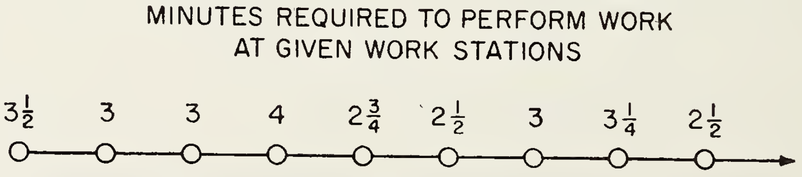


FIG. 8-6. Possible unbalance of production flow before synchronization.

assigned only 3 minutes of work. This can be done in several different ways depending on whether we deal with mechanical or hand-assembly processes. Chronologically, the line is first balanced in terms of equipment capacities, and then a perfect synchronization is attempted through motion and time studies. This may involve additional methods improvement, redesign of segments of the equipment and tool redesign, and occasionally even a redesign of the product to adapt it to a more efficient production process.

If machine capacities were fairly well synchronized on paper in the planning stages, the solution of the problem of production flow in practice is comparatively easy. It is more difficult, however, when the stopwatch reveals different performance time at each operation. Proper selection of equipment can and usually does contribute to a proper balance between work stations. Balance between service equipment, such as material-handling devices and power plant, should follow after balance among individual production equipment is attained. There are usually machines available on the equipment market which can produce given quantities, and one can select the machine that comes closest to the output needed on the production line to keep in step with all other operations. If the discrepancy between output and requirements is too great, it is possible to increase output by redesigning a segment of the machine, by using a slightly different raw material, or possibly by raising the machine's cutting speed.

Minor time lags will still exist, however. These might seem to be insignificant to the average observer. Nevertheless, if because of a limited output capacity of a machine one work station would turn out less than the other, the whole line would have to be slowed down to the output rate of that machine. On the other hand, if the machine turned out slightly more than needed, the operator would get relatively higher wages than his proper output rate would warrant. From the company's standpoint, labor cost at that work station would be greater than necessary. Such minor imbalances can be taken care of by changing some of the holding devices to fast-acting clamps and reducing handling through ingenious devices. Thus, the overload on a work station can be eased and eliminated. If the work station has less than is necessary to do in the available time, the redistribution of the work of several operations may even things out. Alternatively the employee might be used, in addition to his regular duties at that work station, as an inspector, or he might be given some other minor job to take up his slack time.

The saving in time may be small in itself, but the cumulative effect of these tiny time elements can be tremendous. Here perfection is needed in order to attain a synchronized, well-balanced production line. Whereas motion study in intermittent production serves primarily as a means of standardizing motions as a preliminary step to time standardization, in continuous production it helps to establish a smooth flow of production. Of course, in large-scale production it also sets the method the employees must learn in order to be able to perform within the time available.

MOTION STUDY FOR CONTINUOUS PRODUCTION

To avoid rehashing points which were already discussed in the preceding chapter, the reader is reminded of the fact that motion study is predicated upon human ingenuity. Thus, qualitative differences between motion study for intermittent and continuous production really do not exist. The only difference is quantitative; the depth of study is considerably greater for continuous production. The main purpose, as stated, is to help in synchronizing related operations in the production sequence. Therefore, an extremely careful study may be undertaken to find out how to save a few seconds. Every time-saving possibility and every possible labor-saving device must be investigated, and even outside factors may be looked into. For example, if all other efforts fail, one may even investigate whether a change in vendor's shipping instructions could provide the company with a raw material which would require less handling and performance time at a given critical work station. Obviously, if the production line is to move at 3-minute intervals, every work station must only have 3 minutes of work to do; not more, not less. Thus, even seconds may count a lot.

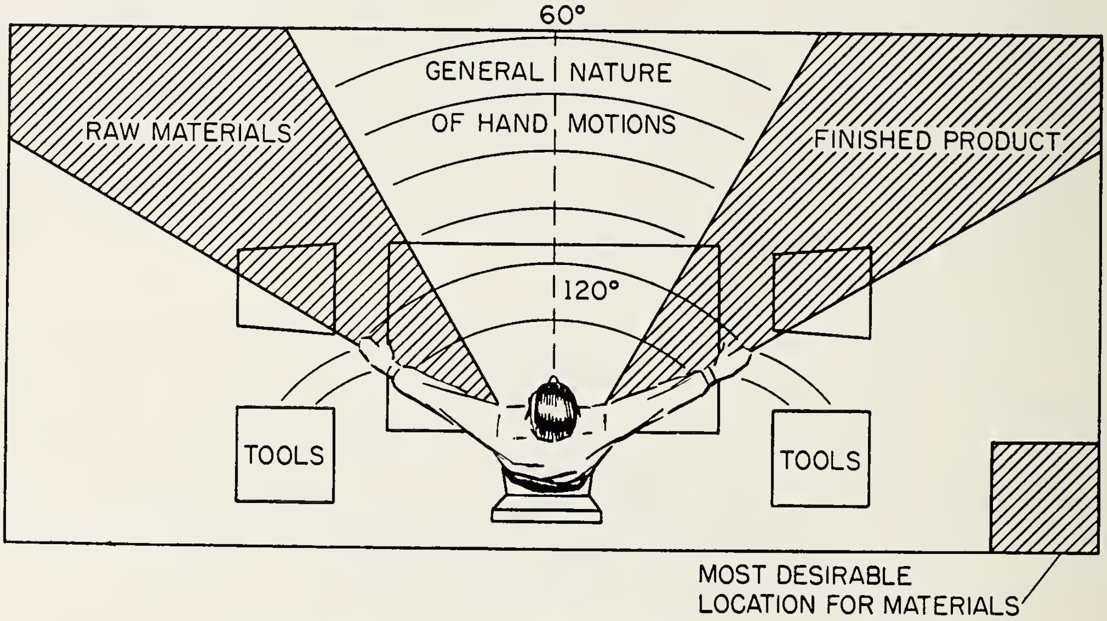
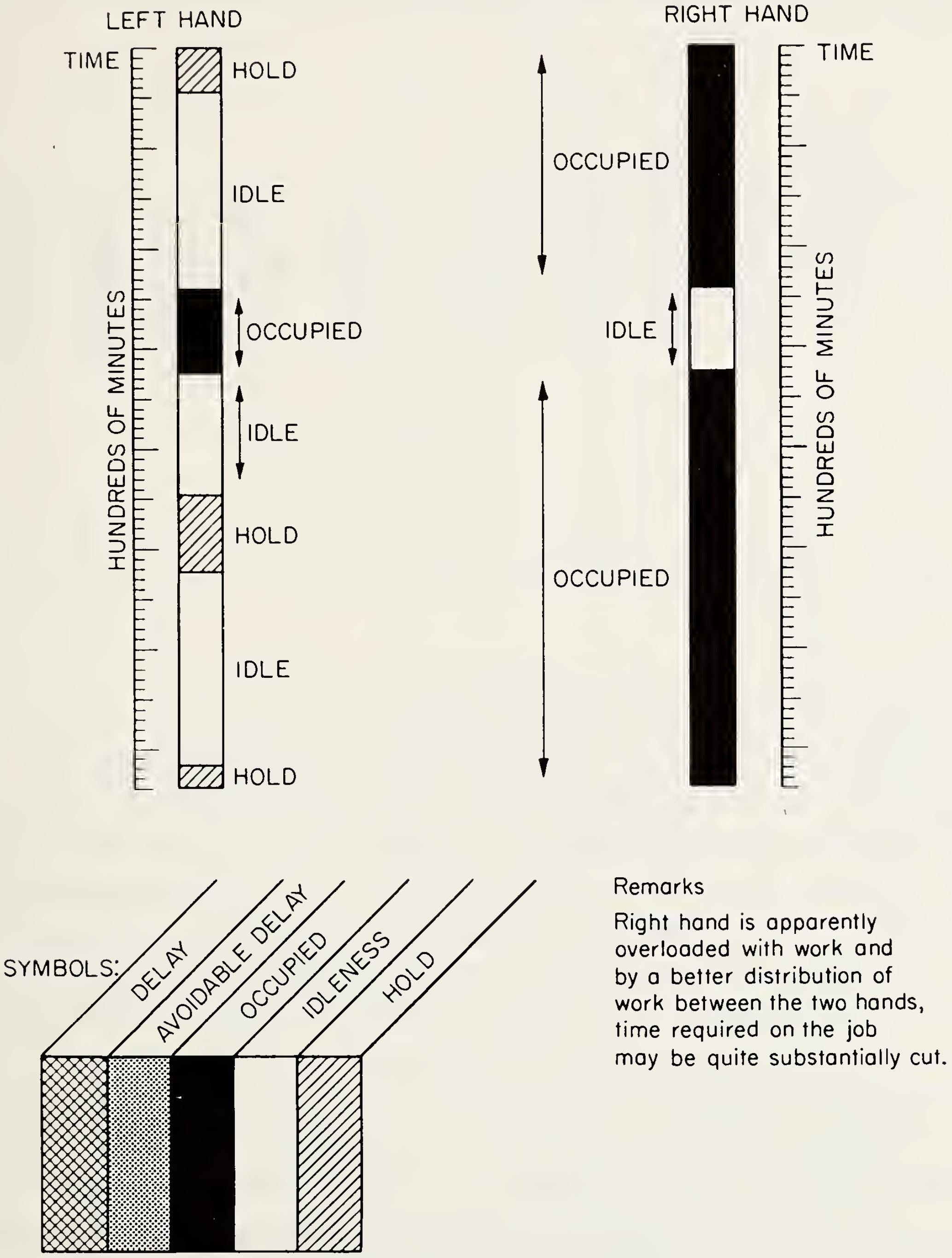


FIG. 8-7. A simple sketch of a work station.

Operation Chart (Time Chart). It was mentioned in Chapter 7 that, when motion study of an operation is made, the movements of the operator's hands are charted to see whether or not improvement is possible. Also, a sketch of the workplace will possibly reveal the shortcomings of the present method and thereby point the way to an improved one. Now the question is what the motion study man is searching for when he observes a work station, such as the one shown in Fig. 8-7. By better correlating the hand motions or by eliminating unnecessary holding or unnecessary movement, the motion study man is able to cut off a few seconds and thus bring the time needed to perform the work assigned to the work station closer to the time for which the production line is synchronized. The operation time chart, Fig. 8-8, is used primarily because only a study of the "time requirement" on the job can reveal a possible need for changes in the motion pattern. An operation time chart is best able to illustrate lack of balance of the operator's hands. However, probably the most important tool in the hands of the planner is the multiactivity time chart, Fig. 8-9, which can depict the relationship between work stations.



Remarks
Right hand is apparently overloaded with work and by a better distribution of work between the two hands, time required on the job may be quite substantially cut.

Fig. 8-8. Operation time chart.

Multiactivity Chart (Time Chart). As already noted, prior to the layout of the plant the plant layout men know with some degree of accuracy the time required to perform the work. The basis of their estimates is the predetermined time standard. When the pilot run starts and the line is started up, actual time study will likely reveal some discrepancy between operations. This discrepancy can be easily seen from a multiactivity time chart such as that shown in Fig. 8-9. A careful study of the various work stations will eventually reveal that a perfect balance is possible. Thereafter, each work station must be studied separately and work simplification must be introduced wherever time saving is necessary.

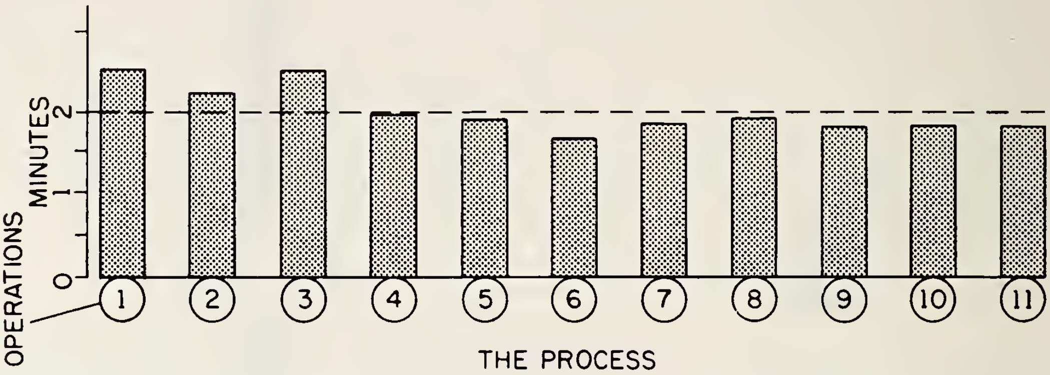


FIG. 8-9. Multiactivity time chart.

TIME STUDY FOR CONTINUOUS PRODUCTION

From Figs. 8-7 to 8-9 it is apparent that, in continuous production, motion study must of necessity be connected with time study. It is important to reveal not only the nature of the motion pattern but also the time which given motions require in order to see how motions can be synchronized with one another on the one hand and operations with one another on the other hand. Furthermore, if a conveyor system is to be introduced, the rate of movement of the conveyor system must be set so that the timing of the movement coincides with performance at the various work stations.

Assuming a constantly moving conveyor system, the assumption can be made that work will flow because the conveyor will set the pace. The time study method will, in such instances, usually not contain allowances, because no one can leave the production line or take a coffee break unless specifically relieved. Thus, the time standard (that is, the allowed time on each work station) will be established on the base time, which admittedly represents a normal work pace by a normally skilled worker. In such a plant, the allowances are incorporated in the time standard only to the extent that, if there are irregular occurrences, the worker must be able to take care of them within the normal time allowed. Employees must be relieved if they want to leave the production line; relief men, then, as well as the normal operators, must be employed. Coffee break may be taken by the whole line at once. In many companies coffee is taken to the work stations at a predetermined time of the day.

TIME STUDY FOR REPETITIVE PRODUCTION

Time study in repetitive production is similar to that described in Chapter 7. When production is in lots, employees must be allowed a certain percentage of the base time for personal needs, irregular occurrences, and other contingencies considered a normal adjunct to the job. In contrast to the job shop operations, in repetitive production time studies can be made with a great deal of care. Accuracy is a must, because the same jobs will be performed again and again. In between production runs, the employees may do some other work (on which there is also an accurate time standard), but the same work will be done at a later time. The time standards are filed or kept by the foreman in a rate book.

In this kind of operation, it is conceivable that the wage incentive system is used because it is possible to influence the relative continuity of plant operations by slow work or deliberate restriction of output. To counterbalance such eventuality, the bonus or incentive pay may begin at less than 100% of the standard.

GROUP INCENTIVES

One of the important uses of time standards in either continuous or repetitive production is in establishing group incentive systems. It must be understood that a production line which consists mainly of hand assembly with hand tools will not necessarily move at a predetermined rate even though the work assigned to each work station is in perfect balance with that assigned to all other work stations. The reason is that there is no conveyor system to pace the performance of employees; hence, a little delay here and there will slow down the whole production line. To avoid this slowing down, the group as a whole may be compensated under a group incentive system.

The group incentive is based on the expected output requirement of each work station individually and of the production line as a whole. Since employees have control over performance at their own work stations and can, owing to the interdependence of work stations, slow down production on the line as a whole, management may decide to compensate the production line collectively. The output rate based on 100% efficiency may be 160 units a day. Since there is no conveyor, the likelihood of reaching this output without some incentive is very slight. The wage incentive (group incentive) may therefore be designed to give the production employees extra compensation for units beyond 140. If there is something to gain, the employees themselves will see to it that no one work station lags behind. A notoriously slow employee will be nagged and bothered by his fellow workers until he either performs as required or seeks a transfer to other work. Occasionally, employees use their own sanctions against a fellow worker who prevents them from earning the incentive.

SYNTHETIC TIME STANDARDS IN MASS PRODUCTION

The use of synthetic time standards is prevalent in mass production for several reasons. First let us consider the plant layout problem. Here the synthetic standards are important because the plant layout experts must, in the planning stages, work with some sort of time data in order to balance work stations. If motion patterns were not translated into time requirements, it would be mighty difficult to balance work stations on paper. That direct time study will be made later does not preclude the necessity for advance information in the preliminary stages. For such purposes the MTM method already mentioned may be excellent. The standard time thus established will not be 100% accurate, but it will be an excellent point of departure.

Although the MTM system may be quite accurate, the difficulty is to identify and classify the various motions. That it relies on the judgment of the analyst is a handicap. Yet we are dealing with a motion study method which takes place prior to actual performance, when only conjectures as to the motions which would be involved in the job are available.

It should also be remarked at this point that there are tailor-made synthetic time study systems which, in contrast to the MTM system, apply only to certain types of activity. Thus, for instance, in the repetitive manufacture of electric motor coils, each coil will vary only in certain respects. If the various motions involved in coil making are known, including some of the circumstances and specifications, it is possible for the company to develop synthetic time study tables. This tailor-made system, often called *elemental times* as opposed to the basic times of the MTM system, is applicable only in the industry in which it was developed and then only in certain types of job situations. In a typical metalworking plant, all sorts of holes may be drilled. A given size hole can always be drilled in a given metal in a given amount of time. Consequently, it is possible to predetermine the time that will be required at given work stations and to use the standards thus established for planning work of all sorts associated with production in general.

Although there are pitfalls in the use of synthetic time studies, generally speaking they are of great help in preliminary planning work in continuous and repetitive production primarily because they permit standards to be established before an operation is actually installed. Hence, these systems are definitely useful in time study and methods design work.

DIFFICULTIES WITH MAINTENANCE OF FLOW

More will be said later about the production control work associated with the flow of production, but at this point mention must be made of the elements about which management must do something at the outset. It is obvious that some products will be rejected because they are defective. The question that arises is what happens to the operation after a given unit is taken out of the stream of production. It is apparent that management must prevent the production line from becoming idle, even for the brief interval required for producing a single workpiece. As a rule, therefore, each work station will have stored a few good workpieces so that one of them can be placed into the work stream whenever a workpiece is rejected and there will be no interruption of production flow. Generally speaking, the inspection station in continuous production becomes merely a part of the production line. If in a TV assembly line a given circuit does not check out correctly, the set is taken out of the stream and replaced by another one. The inspection station tags the rejected unit to indicate what is wrong with it, and the reject is then taken elsewhere for repair. When repaired, it is brought back to the work or inspection station to be used as a replacement for a reject at a later time. Repair of this kind is, of course, handled on a job shop basis.

In some types of production the question is how a unit can be taken out of the production line and replaced with another one. An automobile, for example, would present a problem. What happens is that the automobile is assembled as if nothing were wrong with it, but it is tagged for repair either at the dealer's garage or during the warranty period. In some other instances nothing happens except that the product is tagged or stamped as second or irregular. This is the practice in the garment industry. The product is then sold at a reduced price. Apparently, it is cheaper to complete processing of a bad piece than to repair it or interrupt the flow of production.

COPING WITH VARIATION IN PRODUCTION FLOW

It has already been stated that the flow often depends on employee performance, which management might successfully control by a group or individual wage incentive system. But there are variations in output rates, particularly in repetitive production, when the plant is designed for several product lines. Regardless of how carefully the plant is designed, it is nearly impossible to attain a perfect production flow without scheduling. Thus, to attain a relatively even flow, it is essential to stagger the arrival of materials at a given work station so that none of the machines must wait for raw material. For example, if a machine can produce fewer units per hour than the preceding machine, it will be assigned to some other work while the operation preceding it builds up a sufficient backlog to let the next operator work uninterruptedly.

A common way to arrange the production line in a repetitive type of plant is to build into the line a purposeful imbalance as shown in Fig. 8-10. According to the diagram, operation 1 can produce more workpieces than operation 2, and so forth. Earlier it was stated that repetitive production is possible as long as the products which go through the production line have a similar and preferably identical production process. If the process for, say, five product lines is the same and the time requirements cannot be balanced, production can go on without interruption so long as the first operation is able to turn out more units per hour in each line of goods than the second, the second is able to turn out more than the third, and so on. Thus, product A can be produced in larger quantity at the first station through operation 13. At operation 14 it must wait because that operation is capable of turning out considerably more than 13. Only operation 14 may have to be carefully controlled and scheduled, as by the load control to be explained in Chapter 12. Product B is no problem at all because none of the operations are held up; every work station produces less in the time unit than the preceding operation. Product C is similar to product A.

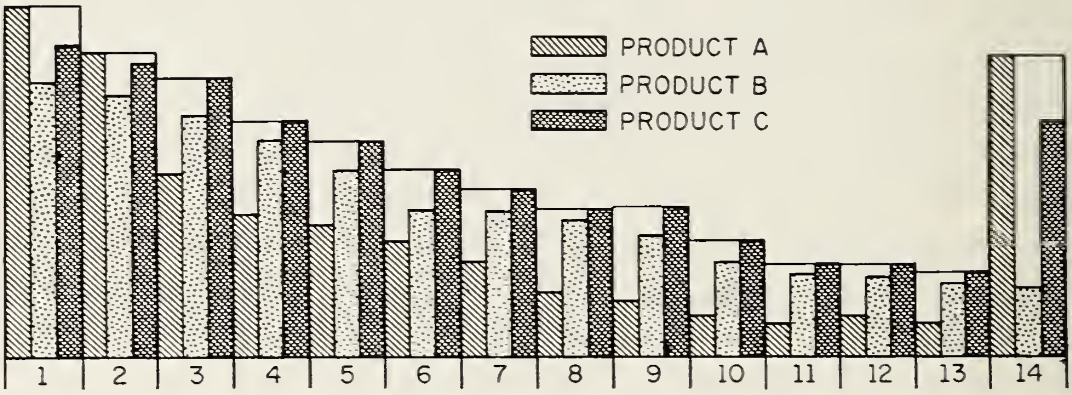


FIG. 8-10. Output of individual work stations per time (per hour).

The preceding paragraph indicates that it is not necessary to have a perfect balance among operations to have an uninterrupted flow as long as the first operation takes less time than the second, third, fourth, and so on. To complicate the problem of plant layout design, let us assume that product D works in the reverse fashion. What is operation 14 for the other products, will be operation 1 for product D. In that case it is up to production control to schedule the production of the goods in such a fashion that plant capacity will be best utilized.

Thus, the plant layout arrangement for repetitive production must be such that product flow is never interrupted in the time sense. This flow can be had so long as the earlier operations always take less time than the succeeding ones. The lot as a whole will flow, but storage and temporary storage of in-process material may be necessary. This kind of arrangement does not necessarily increase the cost of in-process inventory, because overlap scheduling can easily take care of flow. Overlapping simply means that the scheduler starts work on operation 2 of Fig. 8-10 quite soon after operation 1 is started but starts work on operation 3 quite a while after operation 2 is started. In other words, through careful scheduling even this kind of production can resemble continuous production. As products come through one operation, they go into the "live bank," which is nothing but a temporary storage as far as operation 1 is concerned and a raw material supply as far as 2 is concerned. This is just one particular way of setting up a production line for multiple-product mix. Thus even though there is no perfect balance, there is still a flow of production.

There is a problem, of course, if each work station requires more time or less time than orderly production would warrant. The incentive system can help, even in this respect. A case in point is the Lincoln Electric Company in Cleveland, which produces welding equipment in production-line fashion. Even though each work station requires a variable amount of time to turn out the required parts (depending on what equipment is being manufactured), employee cooperation makes production flow possible. Employees know the production requirements necessary to keep up with the line and will do their very best to turn out always the amount the line requires. That they sometimes have to exert themselves a bit more than at other times goes without saying. But the incentive pay is apparently sufficient to make them produce at the rate the production line requires, despite inherent imbalances. Of course, there is an approximate balance between work stations, but in view of the large variety of products which move through the same line, it would be impossible to establish a perfect balance regardless of which welder model was being processed at any given time.

Purists consider only those plants continuous which make single standard items with identical methods. These, among others, are flour, cement, paper, and sugar mills and cereal and food processors. Yet even these plants may not be truly continuous, because they might produce different grades of sugar, cement, etc. requiring additional or different operations toward the end or at the beginning of the production process. Figure 8-11[4] illustrates the point.

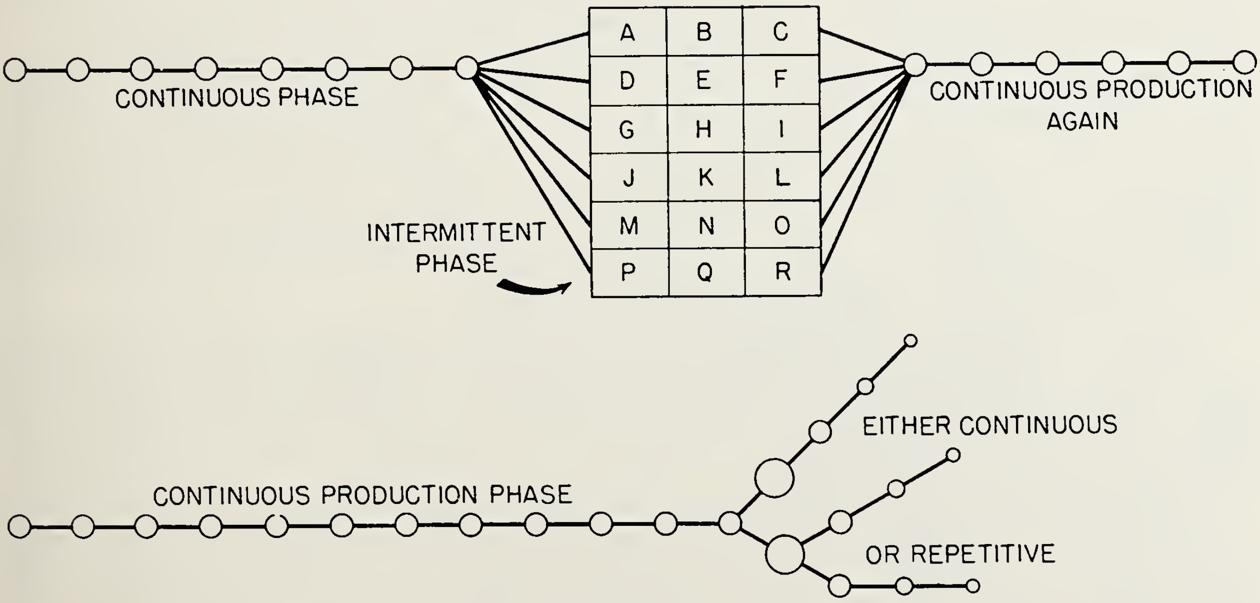


FIG. 8-11

[4] Large circles near bottom of Fig. 8-11 indicate operations where specific production control work must be expended. (For explanation, see Chapter 12, pp. 541-543.)

Most repetitive producers have a standard production process through which their products pass, but in the early and final stages there may be certain differences. Thus, for example, the product may be sent to a department where it is handled on an order basis. Strictly speaking, in the automobile business only the assembly part of production can be considered as continuous production, and some people would argue even this point because different models require special arrangements.

Why must a differentiation be made between repetitive and continuous production? The two are not just theoretical concepts, but are based on practical considerations. Accordingly, production control will vary with the type of production and the type of plant layout. By knowing the nature and setup of production, it is possible to devise a production control system which is capable of creating order. It is a difficult problem to keep track of different orders and different delivery dates, particularly when different customer orders are lumped together at the beginning stages of production and separated again toward the end. In other words, control problems will largely depend on the basic understanding of the physical framework in which production takes place.

AUXILIARY EQUIPMENT AND THE PRODUCTION LINE

Whether in repetitive or continuous production, the flow in the physical sense depends largely on a materials-handling system. The selection of the proper materials-handling system is almost as important as the selection of the equipment. Unless the materials-handling system is properly integrated with the production line and acts as a controlling device, the continuous flow of production is difficult to achieve and must be artificially fostered by a bonus system. To fulfill its purpose, the materials-handling device must carry to and from every work station the workpiece or the product, so that the employee does not waste time in handling materials. Not infrequently, the conveyor is utilized as a workbench. The conveyor is stationary for 3 to 4 minutes and then moves to the next work station. It would be difficult to describe all the materials-handling devices, but it is important to know that production equipment and materials-handling devices must be integrated in continuous production. A disregard of this requirement might cause difficulties in the attainment of a smooth flow of production.

Since in repetitive production it is not always possible to use a constant, fixed-path handling device, it is more difficult to integrate plant layout and materials handling. This is the situation in which a group incentive may control the work flow adequately.

Besides the problem of materials handling, other technical problems must be solved. For example, in repetitive production it is essential to use single drive shafts with individual small electric motors rather than a long drive shaft driven by a large electric motor and in turn driving a whole series of machines. This permits shutting down certain machines without shutting down all of them. Electric power transmission problems of all sorts must be individually solved in such a manner that the specific production requirements are always served. The problems of lighting and factory air conditioning may often be of significance. In many companies control over humidity, temperature, and dust is given special attention because those factors are closely associated with production. In rubber plants, foundries, and forge shops, air purification is especially important because productivity and the work flow may be closely related to it.

These considerations are mentioned to indicate that all equipment used in a company is related in one form or other. A plant is a unit and each part, be it a machine, a conveyor, or a work station, has a bearing upon other units, however remote the relation may be. Although we are not particularly interested in the maintenance function as such, it should also be pointed out that a continuous flow of production often depends on the excellence of maintenance operations. The conveyor system may regulate the flow of production, but unless the equipment is always kept in good working condition, production will still be delayed. That preventive maintenance is involved goes without saying. Maintenance work is usually done when the machines are down during the night or over the weekend.

SUMMARY

Difference Between Intermittent and Continuous Production

Continuous production refers to the activity of creating relatively similar, if not fully identical goods, year in and year out. These goods are usually of large volume and little or no variety. The continuity of production flow cannot always be maintained. If interruption in the production process occurs, the plant may be set up as a repetitive instead of a continuous production shop.

Intermittent production differs from continuous production primarily because the product created is seldom, if ever, a standard type. Repetitive production is somewhat similar to intermittent production, but because the items produced are alike in respect to process and construction, it is somewhat similar to continuous production. In other words a company in repetitive production may produce a variety of items if it can do so on a production line with large-scale production methods. The intermittent producer cannot use mass-production techniques because volume does not warrant a permanent arrangement of facilities. For this reason the intermittent producer has a functional layout, that is, equipment grouped in departments, and transports the materials in process from department to department. The continuous producer, and often the repetitive producer, is able to set up a production line by which the product is carried mechanically from work station to work station. The work stations are so arranged that no backtracking and back-and-forth transportation is necessary. The goods move steadily from one work station to the next. The operation sequence is so planned and arranged that the equipment performs within a predetermined time limit. If the operation has been properly timed and properly arranged, production will flow in a smooth manner. The secret of continuous large-scale production thus lies in the arrangement of equipment and synchronization of work stations.

THE REPETITIVE PRODUCTION PROCESS

Producers aim at cost reduction. An intermittent producer who has products of similar design or carries on production by using similar processes tends to employ large-scale production methods. Consequently he must narrow his production to a few product lines, select equipment which can be converted to multiple uses within narrowly defined limits, and arrange his equipment in such a manner that a continuous flow of production is approached, if not fully achieved. Certain alternative routes may be established and certain junction points and storage areas built in light of requirements, yet the production process can still resemble the operations of a continuously operating plant.

DESIGN AND PRODUCTION PROCESS

In repetitive and, especially, in continuous production the emphasis is on ease and speed of production. Unless the item is so designed that it lends itself to large-scale production, a redesign of the product is advisable. Ordinarily, design engineers are interested in three problems: 1) consumer's taste and satisfaction, 2) functional suitability of the product, and 3) the design of the shapes and forms so that the item can be produced at a cost that places it within the reach of a large market. This is important, because complicated design may drive the costs of production to such levels that neither mass consumption nor mass production is feasible.

Any product which is to be mass produced must have a standard design. Unless customers are willing to accept a uniform product so designed that production is facilitated, it is impossible to produce and sell it at a low enough price to have large-scale distribution.

METHODS AND PLANT LAYOUT

Once a design for mass production is feasible, it is essential to have a plant layout such that production is fast and orderly. To plan the layout, it is often necessary to scrutinize individual work stations as well as all the work stations in relation to one another. A balanced production line is difficult to achieve when a great deal of physical labor is involved in the operation in question, such as in assembly work. Here, each operation is looked upon from the point of view of work simplification.

TIME STUDY AND PLANT LAYOUT

When it is believed that the work assigned to a particular work station equals that of all the others, it is essential to subject every operation to a careful time study. The time study can reveal the time requirement for certain work steps. Motion study and time study are usually done concurrently, since an improvement can be measured only with the help of a stopwatch. In continuous production it is the function of time study to determine whether the time necessary for a given operation is compatible with that necessary for other operations. Unless it is, it is impossible to have a continuous flow of production.

The production process is usually determined by the process engineers. Thereafter, the plant layout people try to visualize the production process by designing the possible plant layout on paper. To help in determining the layout, they may use templets or scale models. They then use the machine manufacturer's information about production output and synthetic time study data to see whether the production flow is smooth. Once the general idea appears sound, it is tried out. Difficulties are smoothed out during the pilot runs. Thereafter the plant can operate efficiently and continuously.

THE CONTINUITY OF PRODUCTION FLOW

Basically, a production line will operate as a unit even though it may consist of dozens of parts. Therefore, it is not sufficient for the plant layout people to set up a logical production line; they must evolve one in which the parts are so dovetailed with one another that a perfect flow develops.

QUESTIONS

8-1. What characterizes continuous production?

8-2. Is it possible to produce something continuously but retain the advantages of intermittent production? Explain your answer.

8-3. What is unit cost?

8-4. What role is played by unit cost in various planning decisions as far as continuous production is concerned?

8-5. Why would unit cost fall with larger volume of production?

8-6. Why would unit cost be considered in conjunction with plant capacity decisions?

8-7. What is the difference between special-purpose, unit-type, and multipurpose machinery?

8-8. What type of machinery would a continuous producer use?

8-9. What type of equipment would a repetitive producer use and why?

8-10. Is it possible to produce an item with mass-production techniques if demand for it fluctuates violently? Explain.

8-11. How is mass production influenced by mass consumption?

8-12. Is it true that mass production is possible only if consumers are willing to forego variety? Explain your answer.

8-13. What aspect of the design is the most important as far as mass production is concerned?

8-14. Does process and methods planning differ in repetitive and intermittent production? Why or why not?

8-15. What factors are determinant in setting the production capacity of a production line?

8-16. What information is used in drawing up a break-even chart?

8-17. How and for what purpose would you draw up a break-even chart?

8-18. What do we mean by fixed and variable costs?

8-19. At which level should the minimum and the maximum capacity of a production line be set?

8-20. How does the plant layout engineer go about setting up a production line?

8-21. What do we mean by "creating" a production flow?

8-22. How do companies determine the rate of production?

8-23. What are the customary roles of motion and time study in the determination of the production flow?

8-24. What charts are utilized by motion study experts to analyze operations along the production line?

8-25. For what purposes is the multiactivity chart used?

8-26. For what purposes is an operation chart used in continuous production?

8-27. How much time and effort should be spent on process and methods study in large-scale production?

8-28. How accurate should time study be in work related to continuous production?

8-29. What use, if any, is made of synthetic time standards in plant layout work?

8-30. What is the difference between "elemental times" and "therblig (basic) times"?

8-31. Explain the technique of synthesizing basic times.

8-32. What do we mean by the abbreviation MTM?

8-33. How do consulting firms determine the time a certain motion should take in the absence of direct time study?

8-34. How accurate is synthetic time study relative to direct time study?

8-35. What is the function of time study in repetitive production?

8-36. Is it necessary to have wage incentive payments in repetitive and continuous production? If so, why?

8-37. Is it easy to distinguish between repetitive and continuous production? Explain.

PROJECTS

8-1. If you were a plant layout engineer, what steps would you take before setting up a production line for a given mass product? Assume further that you are supplied with process sheets indicating the general flow of production. Outline the things you would do.

8-2. What do you have to know about the equipment to be used in production of a given item? List all the information you need to know about the equipment.

8-3. Differentiate between plant layout considerations when alternating a group of products is contemplated and when a single standard item is to be produced on a continuous basis.

8-4. Determine the break-even point for a plant on the basis of the following information: a) approximate sales quantity per month for the coming 3 years varies between 150,000 and 200,000 units, b) fixed cost (equipment) amounts to $80,000 per month for the coming 3 years, c) labor cost, based on a monthly output of 150,000 units would be $160,000, d) material cost per unit of output would amount to $32, e) profit per unit of output should be based on a possible sales price of $40.

8-5. Comment on the situation presented in Project 4. How would the plant operate if the production process consisted of 25 operations and each work station required more than 1 minute performance time?

CASES

8-1. PAPER MILLS ALLIANCE, INC.

The Paper Mills Alliance, Inc., producer of catalog paper, wallpaper, printing paper, paperboard, glassine, good grades of wrapping paper, food-container board, file-folder stock, and other strong paper hybrids, was preparing to consolidate its widely scattered plants. The reorganization was closely associated with the recent acquisition of nearly 75% of the controlling shares of capital stock by the Hinsdale family. As a result of a proxy fight and apparent stock manipulations, the stocks of the company declined very sharply during the autumn of 1960. Besides alleged speculation, the depressed economic conditions might have accounted for the unusually sharp decline of the company's stocks. Since the paper industry is subservient to other industries, it is apparent that poor business conditions will cause severe surpluses in the paper industry. In March, 1961, however, the Paper Mills Alliance, Inc. stock rose again and got within 5 points of its all-time high, which it reached in May, 1960. The rise coincided with an active stock market but could be largely attributed to a change in company operating policies. The Hinsdale family took over leadership: J. J. Hinsdale, Sr. became chairman of the board, and J. J. Hinsdale, Jr., a very capable young executive, until recently a vice-president in charge of production at one of the biggest rubber companies in the United States, took the post of the chief executive.

On the basis of a recent study conducted by company engineers, a consolidation of all company plants was proposed by the new administration. It appeared desirable at this time to build the new plant along the principles of line production rather than according to the traditional functional type of layout.

Paper Mills Alliance, Inc. grew from a small paper mill in 1902 to become one of the nation's largest paper producers. Originally a private firm, it was incorporated in 1917 and enlarged through the sale of stocks. Despite constant growth, the Hinsdale family lost its predominant position as a result of shifts in stock ownership associated with the expansion. In 1923, the company built the most modern paper factory in the United States in a suburb of Chicago. It manufactured wrapping paper and other kraft paper products. At that time Chicago was a more desirable location for the production of wrapping paper than Pittsburgh, where the company continued making fine paper but discontinued the production of wrapping paper.

In 1930, the company purchased the Minnesota Pulp Manufacturing Company, a supplier of 90% of the company's pulp needs. In 1931, Paper Chemicals, which was engaged in the paper refining process, was acquired. After these consolidations the company changed its name to Paper Mills Alliance, Inc. While the reorganization in 1931 was favorable to the Hinsdales

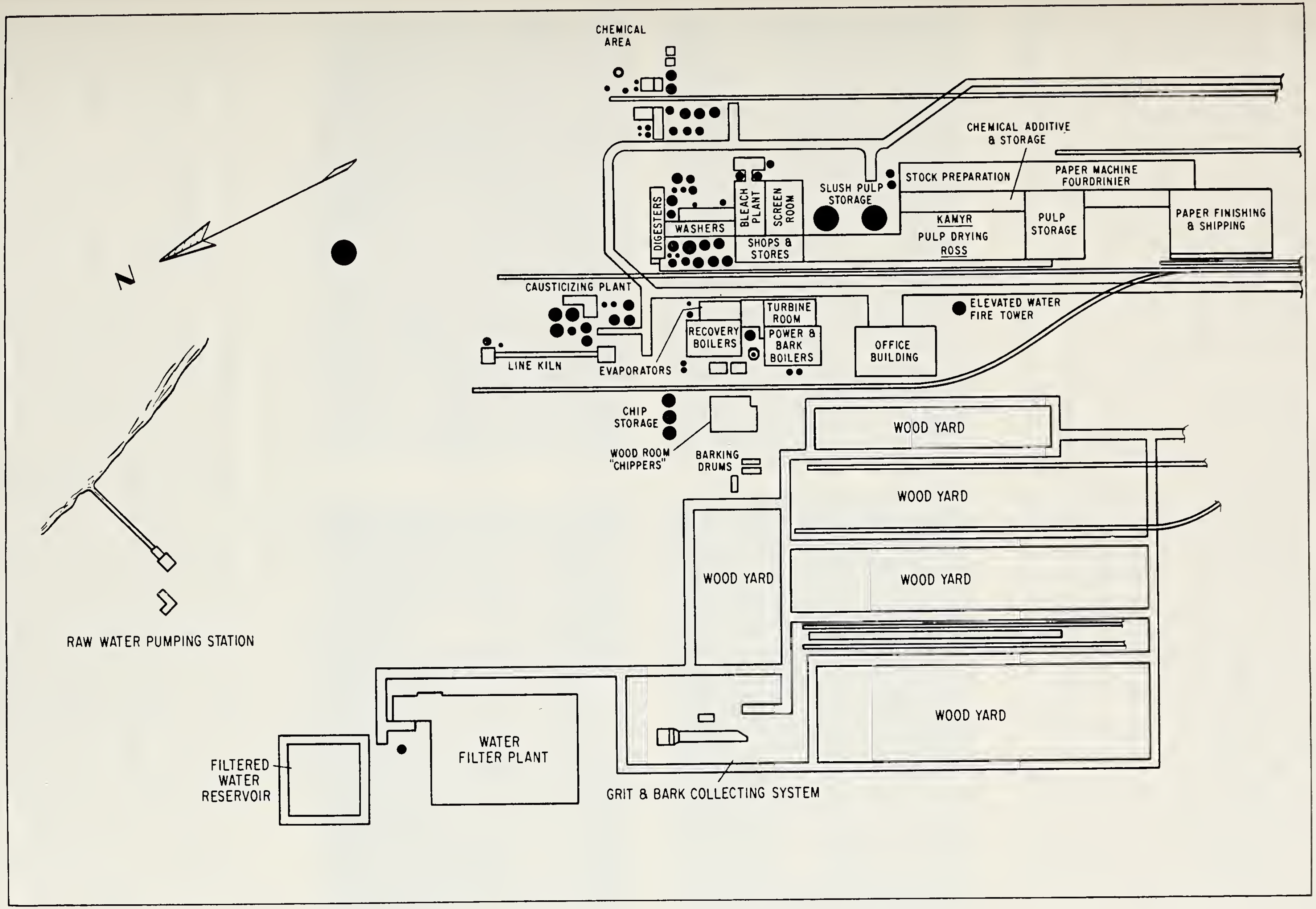

CHEMICAL AREA
CHEMICAL ADDITIVE & STORAGE
STOCK PREPARATION
PAPER MACHINE FOURDRINIER
PAPER FINISHING & SHIPPING
DIGESTERS
WASHERS
BLEACH PLANT
SCREEN ROOM
SHOPS & STORES
SLUSH PULP STORAGE
KAMYR
PULP DRYING
ROSS
PULP STORAGE
N
CAUSTICIZING PLANT
TURBINE ROOM
RECOVERY BOILERS
POWER & BARK BOILERS
OFFICE BUILDING
ELEVATED WATER FIRE TOWER
LINE KILN
EVAPORATORS
CHIP STORAGE
WOOD ROOM "CHIPPERS"
BARKING DRUMS
WOOD YARD
WOOD YARD
WOOD YARD
WOOD YARD
WOOD YARD
RAW WATER PUMPING STATION
FILTERED WATER RESERVOIR
WATER FILTER PLANT
GRIT & BARK COLLECTING SYSTEM

FIG. 1

because of a stock split deal which gave them virtual control, leadership and control were later lost through numerous vertical integrations followed by a series of horizontal integrations with several small finishing plants located in different parts of the country. Again these moves in 1931 led to cost reductions and quicker deliveries vital to company success at the time. These finishing mills refined the various raw paper products through surface treatment such as gumming, coating, embossing, and stripping. After that they went through other finishing operations, such as folding and shaping flat paper into containers and a large number of other paper products.

The paper products of Paper Mills Alliance, Inc. were distributed through wholesalers or sold to direct users or to fabricating plants engaged in different stages of paper finishing; pulp surplus was sold to plants preparing it for further production. Through Paper Chemicals, the company supplied the market with raw material preparates used by finishing mills.

In the company's Minnesota Pulp subsidiary plant, pulp production was in high gear during late spring. However, since wood can easily be stored, and because pulping fibers can be derived also from rag or waste paper, production took place on a year-round basis. Any kind of wood, soft or hard, that is high in cellulose and is inexpensive to obtain can be pulped. Pulping refers to the process of separating natural fibers in five-story high digesters (pulp mixed with cooking liquor is cooked for 8 to 10 hours under intense heat and pressure) and treating them to facilitate their use. The latter treatment takes place in beaters where the fibers are frayed so they will lock together more firmly in the finished sheet. Chemicals are also added during this treatment.

The Chicago plant was by far the largest of the company's specialized plants. Its layout was typical of any other paper plant, such as the layout for the plant shown in Fig. 1, except that pulp was received in prepared form from the Minnesota Pulp subsidiary. Papermaking at the Chicago plant started, accordingly, with treated pulp. The Chicago plant had, in addition to auxiliary equipment, one extremely large paper machine whose wet end is called the Fourdrinier. In this machine, pulp diluted with 99½% water is flooded over a fine mesh of Fourdrinier wire screen. As the screen moves and shakes, it weaves and mats the pulp material together into a soft, wet sheet. The matted paper then goes nearly a mile up and down through at least 50 dryer drums and presses. Wrapping paper comes off the machine in large rolls, which are subsequently transported to other departments where the reduction of these rolls to appropriate sizes and forms takes place. The Chicago plant specialized mainly in the production of kraft and wrapping paper, but it also made some fine paper as a sideline by using the small and relatively slow papermaking machinery. The high-speed machines (moving at 3000 feet per minute) were the company's most expensive pieces of equipment, and it was important to operate them as constantly as possible. Some of the steps in papermaking are shown in Fig. 2.

In the finishing room, the paper is cut to size according to customer specifications. When paper is shipped as rolls, the large reels are slit to size during the rewinding operation. If quality surface treatment is necessary, the paper is sent to the supercalender. In the case of such high-grade paper, the paper also is cut and trimmed and inspected. Finally, all products are packaged, labeled, and shipped.

The converting departments receive the paper from the paper mill in raw paper form. After the fibers are matted into paper barely able to support its own weight, the paper goes through the converting departments which usually fulfill two different groups of tasks at the other end of the paper machine: 1) presses the wet paper through a series of press rolls and dryer drums, including a calendering machine which is a part of the overall papermaking process; then 2) surface treats (by gumming, embossing, coating, etc.) the paper in a series of appropriate operations using a large number of smaller machines. The paper is treated with clay, alum, resin, casein, talc, etc. depending on the required quality. (In some companies only cutting the paper to size or shaping it into bags, boxes, containers, etc. is called converting.) For these operations either multipurpose or special-purpose machines are used, depending on the ultimate use of the product. All in all, the company turned out more than half a billion pounds of paper per year.

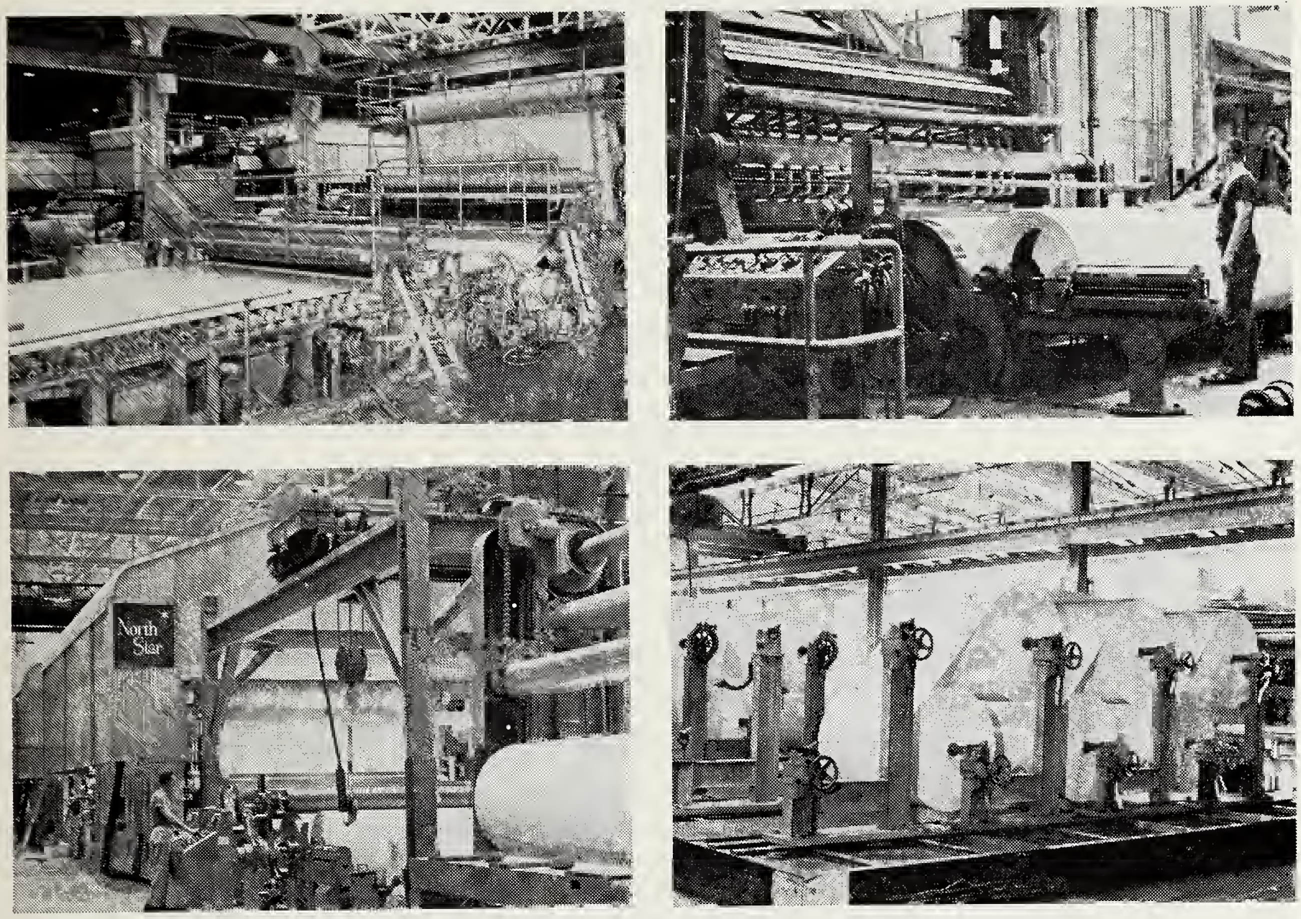


FIG. 2. Steps in papermaking. (Courtesy of Oxford Paper Co.)

Since new items were frequently added to the product line, production control was difficult. As a result of widely scattered operations, it was not unusual that there was duplication of equipment despite functional layout. Since foremen scheduled production along with their ordinary duties of supervising men and solving technical details, it was difficult to find out when and if a given piece of equipment (which was used by another department) was free. Lack of plant layout according to a unified plan occasionally caused the same type of equipment to be located in two or three different departments. Thus, in case of rush orders, goods in process were transported from department to department. Although this practice was recognized as being inefficient, the steady increase in productive facilities and a haphazard distribution of responsibility among foremen for the crews operating the machines made well-planned effort difficult. When it was advisable to take up a new item, it was usually assigned on an informal basis to that foreman who was least busy at the time. As a result of an unsystematic allocation of departmental responsibility over the years, however, foremen became overburdened; also, finishing equipment located in several departments had become excessive. Subsequent failure to make full utilization of company facilities was therefore largely responsible for lack of adequate profitability.

As a result of unsystematic plant layout, the company encountered periodic production difficulties despite the adequacy of plant capacity. Thus, the rising volume of business could not be handled even though equipment was available. Costs fluctuated irregularly because of inadequate utilization of the equipment, which was scattered all over the plant in different sections. It was next to impossible to route material through the shop effectively because operations had to travel back and forth from department to department and often from one plant to another. Inter- and intraplant transportation, material handling, and machine setups were excessive.

The fact that the company did not rely on outside suppliers for pulpable material was a significant benefit and compensated for some of these inefficiencies. Through waste utilization of a subsidiary plywood plant, prices on raw materials were much less in the long run; hence, it was felt that the company gained more in lower procurement costs than some integrated plants which had to debark, chip, and pulp lumber from scratch. Thus the plant layout arrangement served the company's purposes despite its inadequacies. However, the most serious problem resulting from excessive inter- and intraplant transportation was the difficulty of keeping track of orders floating in transit. All these difficulties added to the costs of production. The new management had given considerable thought to these problems and seriously considered a consolidation of the various plants into one large plant, which would be laid out in a unique fashion. Among other features, chipping and pulping would be integrated with papermaking.

Company engineers were confident that it would be far more efficient to produce in an integrated plant than in the existing scattered plants. The new plant would be in a central location and laid out partially for straight-line and partially for repetitive production. Adaptability to consumer needs would branch out from the line layout, but only at the finishing stages. The contention was that this layout would gain the advantages of both functional and line layouts without assuming their disadvantages. The industrial engineers stated that such an operational arrangement would permit large-scale production of different items and yet permit manufacturing to customer specifications at the same time.

The investigating engineers were convinced that the proposed layout would have a favorable effect on efficiency and result in a substantial decrease in overhead cost per pound of paper. The overall savings over the plant's life would more than offset the cost of building a new plant and for the scrapping of still usable, but inefficient equipment. Furthermore, if the location was properly chosen, it would also be possible to enter a low-wage district where the bargaining power of the Pulp Sulphite and Paper Mill Workers or the United Paper Makers and Paper Workers International Union (an AFL-CIO affiliate) was somewhat weaker. This is an important consideration since the labor employed in pulp- and papermaking commands a relatively high wage rate. Since machinery utilized in the paper industry is complicated to operate, it requires skilled and responsible men. Many segments of the papermaking process were fully controlled by workers assigned to the equipment in crews. The Fourdrinier section of the papermaking machine particularly depended on teamwork of men, especially if trouble developed. The overflow of matted paper—just as when a water hydrant bursts—required quick action, and members of the crew could not very well wait until the boss gave orders. In the Minnesota Pulp plant, quite frequently the crew leader decided, for instance, on the cooking and beating time and even on the makeup of the papermaking formula. Thus it was important to take key personnel along regardless of where the plant moved, since well-experienced paper workers (working together as a crew) are not found everywhere in the country. A relocation would, however, permit replacement of most, if not all hand operations with automatic devices. Instrumentation could not be possible under present arrangements unless the production volume was large enough to warrant the expensive control devices. Otherwise, the pulping operation as well as some of the other steps in the papermaking process lend themselves well to a semiautomatic control. Thus the contemplated new plant could be highly automated.

A vital factor in this plant relocation and plant layout plan was the reorganization of factory personnel, including that of key personnel of Minnesota Pulp, which were needed in the new setup. It was recognized that the heart of production was the supervisory group. All these men had been with the company for many years and knew their jobs well. Also, the specialization among these men was far advanced; some of them were experts in pulp making, pulp preparation, papermaking, or in certain phases of the finishing operations. It was, however, questionable whether the men could be used equally well under the line layout or partial automatic processes. Such an arrangement would make supervision much easier, but a decline in authority and responsibility might not please some of these men who had been accustomed to greater power. Under continuous production, some of the foremen would be relegated to figureheads mainly concerned with routine matters rather than with production decisions.

To illustrate the decision making as originally practiced by foremen, it is essential to understand that under the functional layout the same machines were utilized to perform similar operations on a number of different products. This was particularly true in the finishing departments or in beating (including mixing and associated refining in a mixer known as a jordan). When material costs changed, it was in the interest of the company to shift to the production of that product which commanded a better raw material price. To get the same quality mix, even though different materials were used, the cooking time, the pressure, and the blade movement and agitation in the jordan had to be adjusted accordingly. When certain high-grade paper sold faster than low-grade paper, the finishing department could decide without much hesitation on making the high-quality paper which commanded ordinarily a higher profit margin. On which order the respective foreman wanted to work depended on his decision. It was within the authority of a foreman to decide on the schedule of production so that the best cost structure could be achieved. Foremen were considered good if they were able to meet consumer demand yet produce, along with customer orders, fast-moving stock items at the best unit cost, that is, paper products which were more profitable. Furthermore, a shift in scheduling was often necessary to make certain of getting full use out of equipment. When one type of product did not provide enough work to keep equipment busy, foremen had authority to make a quick change without authorization from their superiors. Therefore, if the existing and satisfactorily functioning functional layout were to be turned into line layout, the management would be faced with the possibility of having identical machines, in two or more production lines, busy only part of the time unless central production control could successfully plan their use. The significance of this cannot be underestimated, because some of the papermaking, coating, and supercalendering machines can cost from several hundred thousand dollars up to millions of dollars. The possibility of the expected difficulties had to be reduced in advance if the line layout was to be a success. In a similar manner, the current inadequate utilization of facilities had to be eliminated.

Company engineers proposed a sequential layout wherein the gradually developing pulp stock was to flow in water suspension from the time production started in the pulp digester in the one end of the building, adjacent to the stockroom facilities, until the wet sheet of paper came off the papermaking machine and proceeded through a series of presses and dryers. Movement from the preliminary stage of paper preparation to the next was to take place by means of pumps. Chemicals, colors, and filler were to be added to the pulp in the beating process. Obviously, the layout had to be such that several different paper grades could come out of the vat where the beating process was accomplished and from the subsequent lines of paper machines, even though all these machines were an inherent part of a one production line system. In other words, the layout considered would enable a continuous production line to turn out a large number of different products. The layout therefore was a technically clever compromise between the line-layout and the functional-layout principles.

The pulp had to be so prepared that it would lend itself to the manufacture of widely varied items in the several finishing departments. Production flow was to be river-like up to a point. From there on, the flow would branch out into different sublines ending up in different products. The flow should be aided as much as possible by a highly specialized handling process resembling the conveyor system.

The idea of integrating papermaking from debarking, chipping, pulping, etc. on till the finished paper came off at the other end, promised low-cost operations. If it could be carried out successfully, it would make Paper Mills Alliance, Inc. one of the most efficient and, presumably one of the most profitable, paper mills in the country. Probably for this reason the stocks of the company skyrocketed after announcement of the plan, although the question that remained was whether it was possible to have an integrated production process capable of continuously producing items so different yet still so similar. The proposed machine layout of the new plant is shown in Fig. 3. The paper machine would be able to produce paper 450 inches wide at an unusually high rate of 4000 feet per minute.

Paper Mills Alliance, Inc. came out with the line layout idea, where supercalendering would be a part of the paper machine and the reel could be switched to it by remote control, largely because the engineering department had conclusively indicated that productivity would increase sharply with the increase in the size of the mill. Thus, the larger the mill, the greater the unit production achievable per man-hour of labor. Productivity tends to vary according to the grade of the paper. Fine papers are usually made on relatively small papermaking machines with low productivity; while wrapping paper lends itself to high production with expensive equipment. Nevertheless, if the volume is large, special devices can be built into the machines to effect greater productivity regardless of grade. In these considerations, the possibility of producing newsprint paper in a large integrated mill has played an important role. Until then, Paper Mills Alliance, Inc. had been unable to sell to big newspaper chains because the many interrelated operations were too far apart. Although a somewhat integrated paper mill in a sense that equipment

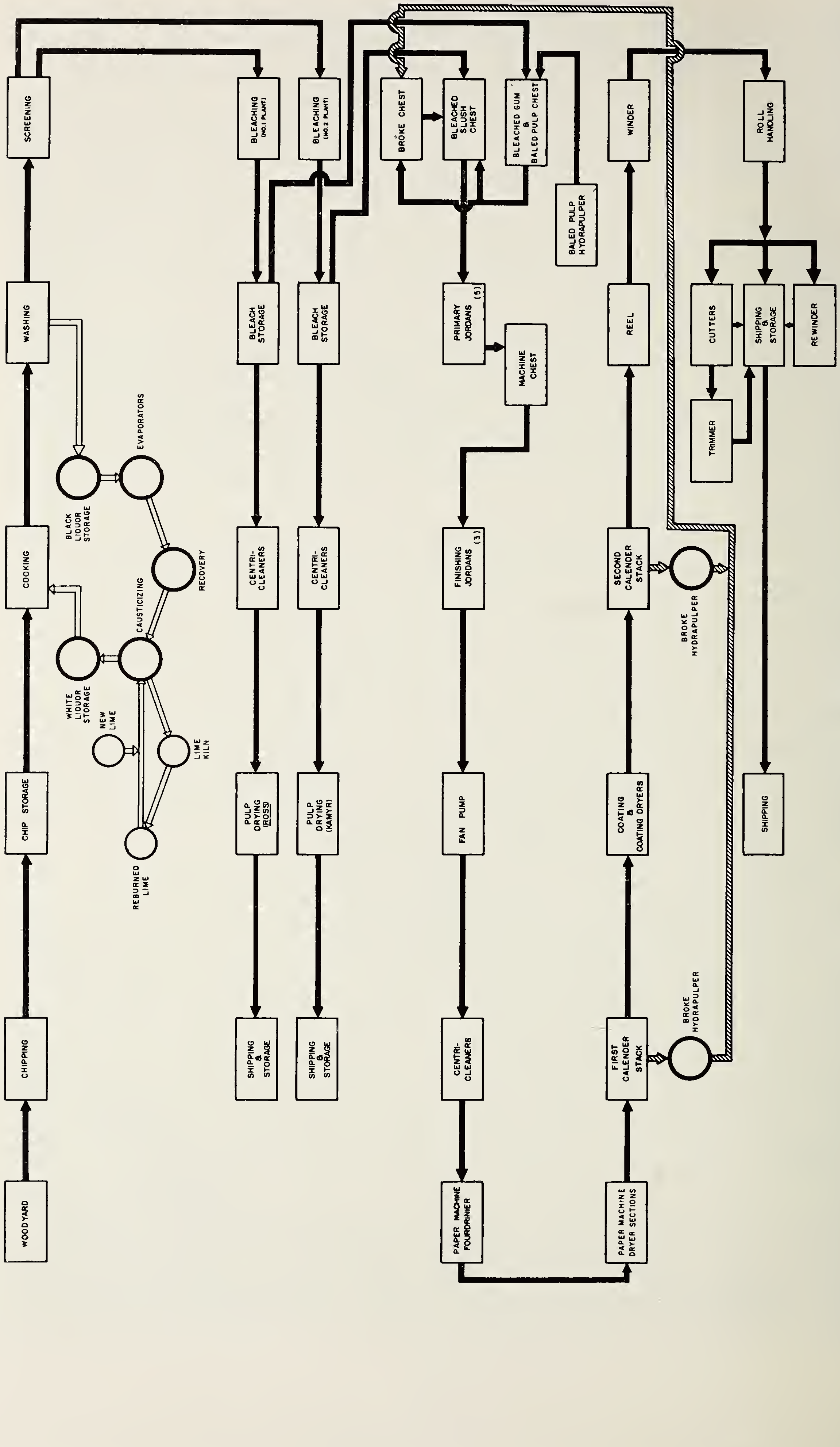

WOODYARD
CHIPPING
CHIP STORAGE
COOKING
WASHING
SCREENING
BLACK LIQUOR STORAGE
EVAPORATORS
RECOVERY
CAUSTICIZING
WHITE LIQUOR STORAGE
NEW LIME
LIME KILN
REBURNED LIME
BLEACHING (NO.1 PLANT)
BLEACH STORAGE
CENTRI-CLEANERS
PULP DRYING (ROSS)
SHIPPING & STORAGE
BLEACHING (NO.2 PLANT)
BLEACH STORAGE
CENTRI-CLEANERS
PULP DRYING (KAMYR)
SHIPPING & STORAGE
BROKE CHEST
BLEACHED SLUSH CHEST
BLEACHED GUM & BALED PULP CHEST
BALED PULP HYDRAPULPER
PRIMARY JORDANS (5)
MACHINE CHEST
FINISHING JORDANS (3)
FAN PUMP
CENTRI-CLEANERS
PAPER MACHINE FOURDRINIER
PAPER MACHINE DRYER SECTIONS
FIRST CALENDER STACK
BROKE HYDRAPULPER
COATING & COATING DRYERS
SECOND CALENDER STACK
BROKE HYDRAPULPER
REEL
WINDER
ROLL HANDLING
CUTTERS
SHIPPING & STORAGE
REWINDER
TRIMMER
SHIPPING

FIG. 3

was available, its production was primarily on a job order basis. Since one of the Hinsdale sons was an executive of a big newspaper chain, it would be possible to get into the newsprint market, provided the company was able to supply the chain with cheap yet high-quality newsprint paper.

The new plant, if completed, was to be operated on a three-shift basis 7 days a week. Care would be exercised not to have anyone on the payroll who drew overtime pay. There would not be shift differentials. A more intensive utilization of the plant facilities and the greater output of the plant as a whole would greatly reduce overhead charges and permit the scrapping of obsolete equipment without replacing it. Some of the expensive equipment would be rebuilt and integrated with the newly acquired facilities wherever technically feasible.

The engineers indicated that the new layout would permit easy control over orders but that systematic production control and materials control would have to be established in order to take care of scheduling, mixing of ingredients in the beaters and the jordan and the chemical treatment. With such an arrangement deliveries would be much better than with supervisory personnel doing most of the scheduling and chemical control. The routing and transporting of materials in process would be a routine problem rather than an ever-existing agony. It was admitted, however, that the flexibility of the plant to changing demand would be reduced somewhat and changeovers to gain savings in material costs would also be greatly reduced, even though this had been a very successful practice in the past. However, some smaller equipment, when properly rebuilt, can provide some degree of flexibility. Before putting the plan into effect it was advisable to ascertain whether the initial installation contained any significant errors, particularly whether the 450-inch web and 4000 feet per minute speed on the papermaking machine were technically feasible. Evidently, once installed, the equipment, either bolted down or mounted in cement, would be very costly to rearrange again. Thus, it was desired that any hidden or apparent defective features of the proposed plant layout plan should undergo careful scrutiny while rejection of the plan and necessary adjustments in the proposed layout were still possible. Questions such as production control and foremanship utilization, machine loading under conditions of line layout, and the effect of future changes in the paper products for which the plant was built were to be answered beforehand.

Questions. The student should notice the difference between intermittent and continuous production. Furthermore, the repetitive nature of paper production should be considered. This is apparently a combination of intermittent and continuous production.

Clearly there are shortcomings in the present production method of the company. Therefore, the student should undertake the usual analysis:

1. What are the symptoms at present indicating that company efficiency is not as high as it should be?

2. What causes these shortcomings?

3. How could they be solved without relocation and without a costly changeover from functional plant layout to line layout?

4. Can the proposed layout alleviate all the above problems?

5. What problems do you anticipate as far as the new layout is concerned?

6. What, if anything, is wrong with the *Wall Street Journal*'s statement that "Paper Mills Alliance, Inc. wants to do what the automobile industry has already accomplished; namely, to produce on one single assembly line dozens of custom-built cars." Can the paper industry be compared with the automobile industry? If so, is it feasible in the paper industry to attempt to set up a production line in a similar manner?

7. Criticize the plant layout suggestion and state in a technical as well as in a theoretical sense your objection to the proposed plan.

8. For sake of argument, agree with the engineers' proposed plant layout change and discuss why the relocation and the plant layout arrangement should be undertaken.

9. List the advantages of the proposed production line technique to be applied to a plant characterized by intermittent operations and contrast them with the disadvantages.

10. It was stated that the stocks of the company skyrocketed with the news that the Paper Mills Alliance, Inc. wanted to install a production line for paper products. If you were a stockholder, would you have sold or held your shares of stock? (Assume that you are not a speculator, but a serious investor.)

8-2. PLYWOOD DIVISION, MINNESOTA PULP MANUFACTURING CO.

Minnesota Pulp Manufacturing Co. is a division of Paper Mills Alliance, Inc. Its Plywood Division, in turn, is one of the plants which supply the parent organization with pulpable raw materials.

The plants of Plywood Division are located in Kittson and Roseau counties in the northwestern section of Minnesota. However, prepulping operations are often performed in Lake of the Woods, where some depositories of debarkers are located. The waste material is ultimately processed by Minnesota Pulp Manufacturing Co. to be turned over to the various processing plants of Paper Mills Alliance, Inc.

In 1961 a major reorganization was contemplated which also affected the operations of the Plywood Division of Minnesota Pulp Manufacturing Co.[5]

Paper Mills Alliance, Inc. reorganization, coupled with the financial difficulty in which the Plywood Division found itself, created a problem which had to be handled with considerable care. The Plywood Division had its own problem. The Plywood Division was no longer competitive and in 1959, when the market price which governs its major product fell to $64 per 1000 square feet, its operations had to be suspended until the time when market price again reached at least $72, the plant's break-even point under usual output. Below this price the company could not operate without substantial losses. The company's major product, which took up 90% of the plant's capacity, was plywood panel.

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[5] From now on referred to as the Plywood Division as if it were an independent company. Actually, it operates as an independent division, but still it belongs to and its policies are governed by those of Minnesota Pulp.

When six months later the pickup in building construction drove up plywood panel prices to $75, the Plywood Division recalled its 600 employees. Obviously, during the shutdown, overhead and maintenance costs went on, causing a total loss of $¼ million at the end of the year. During the past few years the company many times experienced similar problems which caused losses of considerable magnitude. In view of the fact that consumer demand, and so capacity utilization, determined Plywood Division's profitability, price fluctuations put Plywood Division in a precarious position.

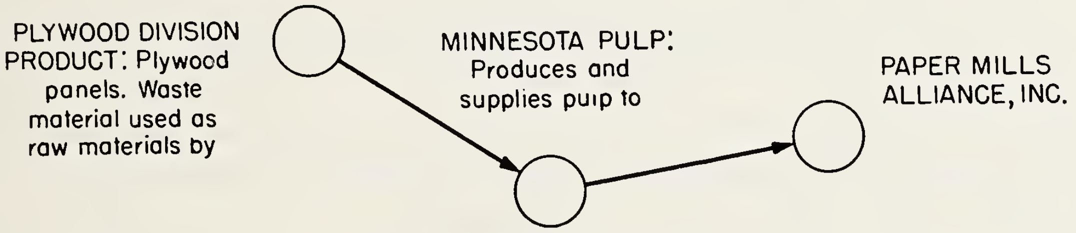
PLYWOOD DIVISION
PRODUCT: Plywood panels. Waste material used as raw materials by
MINNESOTA PULP:
Produces and supplies pulp to
PAPER MILLS ALLIANCE, INC.

Fig. 1

However, the difficulty experienced by Plywood Division caused similar problems in all plants related to one another as illustrated in Fig. 1. When Plywood Division was shut down, Minnesota Pulp (another division of Paper Mills Alliance, Inc.) was out of raw materials to some extent because the waste material derived from plywood panel production was used for pulping. Also, it was costly to purchase pulpable materials from other producers, not to mention the higher costs of transportation relative to the value of the raw material.

Thus, layoffs in the Plywood Division made it difficult to operate pulping plants. As a remedy, the Plywood Division kept on operating even though it was selling below its own costs of production. The pending reorganization of Paper Mills Alliance, Inc. was therefore favorable to some extent as far as the Plywood Division was concerned. It was in the interest of both Minnesota Pulp and Paper Mills Alliance, Inc. to do something about assuring an uninterrupted flow of pulpable materials to the pulping plant.

Large-scale operations in the finishing stages of papermaking required an increased quantity of pulp from Minnesota Pulp Manufacturing Co. Since the supply of pulpable material coming from Plywood Division was reasonably priced and very vital to the other affiliated companies, there were great hopes that the operations of the division might be converted along with the parent organization to large-scale methods. Since rivers and lakes are the only feasible means of transporting lumber, Lake of the Woods county would retain its strategic position as far as Canadian fir was concerned.

The production problem and the conditions around it boiled down to a few related facts: the break-even price per 1000 square feet of plywood panel was $72. By increasing plant capacity, it was possible to bring down the plant's break-even point to the $58 or $60 level. At this level by-product utilization recovers some of the operating expenses. Larger volume of plywood production would increase the waste materials essential to pulping. The demand for plywood is highly elastic, and if the prices are lowered, a more than proportionately larger volume can be sold than the price concession seems to warrant. An enlargement of plant capacity might then turn out to be profitable. This profitability would assure Minnesota Pulp of large quantities of cheap raw materials. When the reorganization of Paper Mills Alliance, Inc. was complete, Minnesota Pulp would have to turn over nearly 50% more paper pulp of high quality to finishing plants. If Paper Mills Alliance, Inc. could enter the newsprint market, and that seemed possible, it was reasonable to assume that Plywood Division would also be converted to continuous operations. As long as prices could be kept low, and the raw material and by-product utilization was assured, Plywood Division was the key to success of the Paper Mills Alliance, Inc. reorganization.

The superintendent of the Plywood Division, supporting his argument with statistical data, was in favor of reducing the break-even point and increasing the plant's output capacity. According to his statistics, a definite trend toward increasing plywood needs was developing. From his statistics it was apparent that plywood sales had increased fourfold in ten years and it appeared likely that this trend would continue. He further asserted that, unless he could convert his operations to low-cost production techniques based on the principle of continuous production, it would become increasingly difficult to stay in business. He pointed out that U.S. Plywood Corporation, International Paper Company, Georgia-Pacific Corporation, and all the other producers in the plywood business were expanding their facilities and unless the Plywood Division kept step with them, the company's 600 employees would soon be looking for jobs in an area where everybody depended on the lumber business.

Although company operations would lend themselves to continuous production, in the past intermittent and occasionally repetitive production had been practiced. Ordinarily, the production process consists of the steps shown in Fig. 2. It was argued that with meticulous attention paid to details it should be possible to create a continuous flow of production. The present method of floating the trees down the rivers, lakes, and canals might have to be changed, because of its time-consuming nature. Furthermore, during

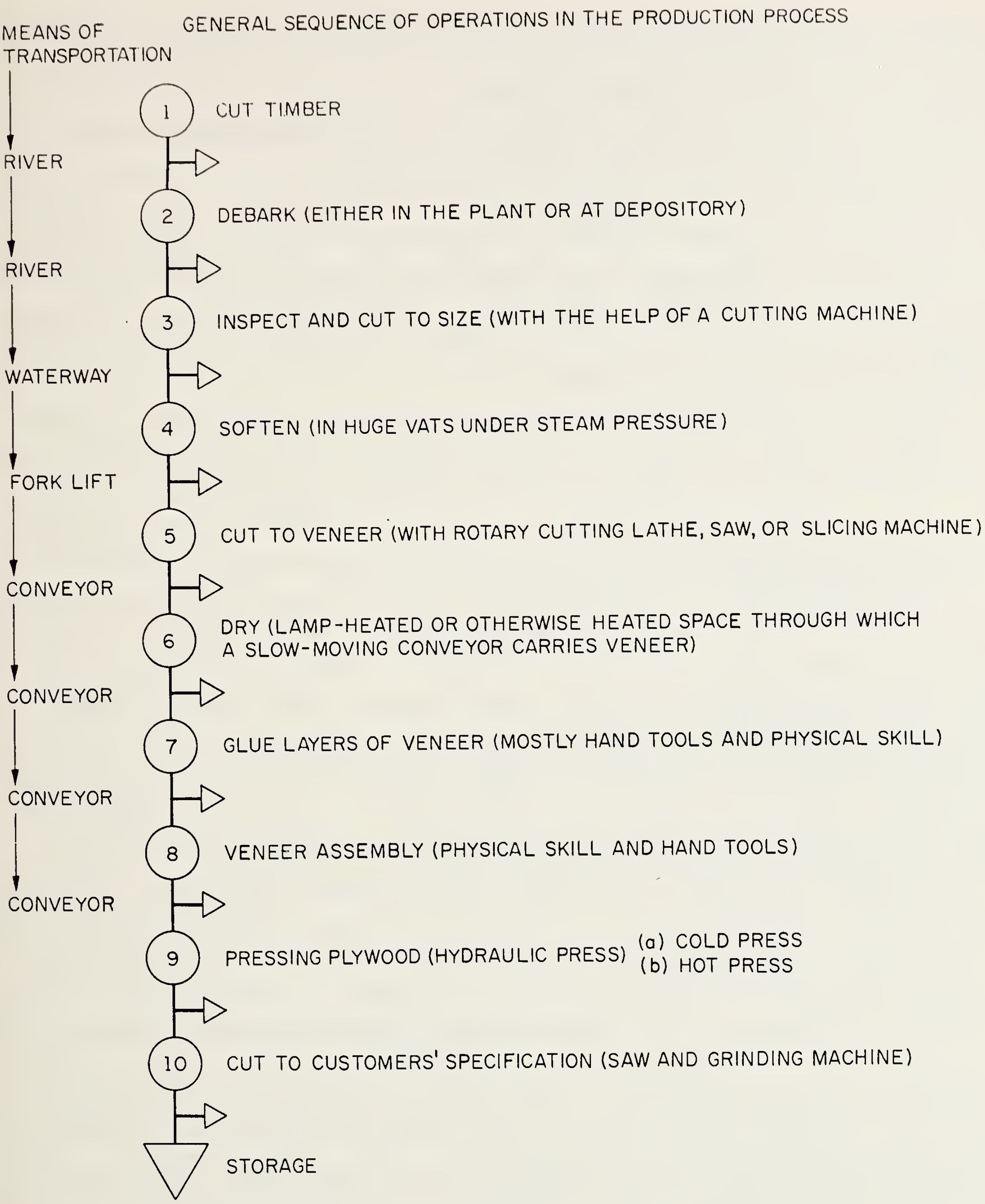
MEANS OF TRANSPORTATION
GENERAL SEQUENCE OF OPERATIONS IN THE PRODUCTION PROCESS
1 CUT TIMBER
RIVER
2 DEBARK (EITHER IN THE PLANT OR AT DEPOSITORY)
RIVER
3 INSPECT AND CUT TO SIZE (WITH THE HELP OF A CUTTING MACHINE)
WATERWAY
4 SOFTEN (IN HUGE VATS UNDER STEAM PRESSURE)
FORK LIFT
5 CUT TO VENEER (WITH ROTARY CUTTING LATHE, SAW, OR SLICING MACHINE)
CONVEYOR
6 DRY (LAMP-HEATED OR OTHERWISE HEATED SPACE THROUGH WHICH A SLOW-MOVING CONVEYOR CARRIES VENEER)
CONVEYOR
7 GLUE LAYERS OF VENEER (MOSTLY HAND TOOLS AND PHYSICAL SKILL)
CONVEYOR
8 VENEER ASSEMBLY (PHYSICAL SKILL AND HAND TOOLS)
CONVEYOR
9 PRESSING PLYWOOD (HYDRAULIC PRESS) (a) COLD PRESS (b) HOT PRESS
10 CUT TO CUSTOMERS' SPECIFICATION (SAW AND GRINDING MACHINE)
STORAGE

Fig. 2

winter, most of the lakes and rivers were frozen, which prevented continuous operations. In other words, the fixed charges could not be applied to 12 months production.

In calculating production capacity, the Plywood Division expected plywood prices to fall no lower than $60 per 1000 square feet. Although an investment of nearly $10 million is needed to adapt current facilities to better methods and thereby increase the present annual capacity of 50 million square feet to one of 75 million square feet, the investment would bring down the break-even point to \$58 as opposed to the current \$72. The latter is predicated on the assumption that facilities depreciate in 20 years. With this change in mind, it was felt that Plywood Division could become one of the most efficient plants in the country; it could even compete with giants like Georgia-Pacific Corporation. The sales department indicated that it would not be necessary to make a sales forecast to determine the demand for the company's product, because plywood demand is fully elastic. As long as the company could sell at the market price, all the output could easily be marketed. Relative to present sales, 75 million square feet of plywood seems an enormous volume, but since railroad and other facilities are adequate to handle a larger volume, no difficulty was foreseen.

Timber is available in the area. Plywood Division has access to old-growth Canadian fir floated down the rivers and lakes or transported in box cars unloading adjacent to company facilities. Since high-grade veneer comes from old and thick logs of fir trees, the company has little problem with raw material supply, despite the recent difficulty with log trading.[6] In recent years there has been difficulty in finding enough deep or shallow clear peelers to go round. Until now, the veneer was immediately cut after inspection. A great deal of the surface of veneer strips, often up to two-thirds of the entire thickness, was sanded away to get rid of the sapwood which made the plywood wavy and reduced its commercial value. Process engineers contend that log cooking is applicable not only in hardwood-ply but also in softwood-ply production. Before the logs from which veneer is sliced get to the cutting lathe, they must be steamed to soften the fibers and melt pockets of hard sap. It is contended that this will increase yield and not only clear wood, but also sapwood can thus be converted to plywood veneer. Furthermore, this log cooking may speed up the cutting operations by 50% in view of the scalpel-sharp cutting ability of the rotary cutter's blade over softer surfaces. The additional advantage of this improvement is the reduction of waste and inspection cost. Hot logs can be cut to much closer tolerances than cold. Of course, this necessitates greater care in felling, where a change in tools must be made to prevent men from damaging the upper part of the trunk. It is suggested therefore that a new production setup would utilize slings instead of big pincers which tend to pierce the bark. The loggers would have to be

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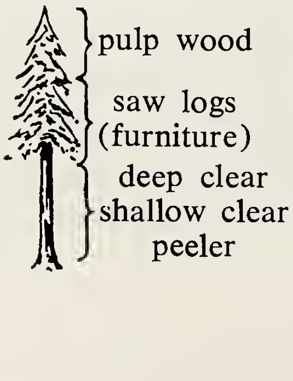
[6] Log trading refers to the practice of exchanging with other producers that part of the log not used by the company. Thus, Plywood Division depends on the so-called deep clear and shallow clear peelers (that part of the log nearest to the ground) because the lowest portion of the fir is clear wood, containing practically no knots.



The diagram illustrates the fir and its use in the plywood business. Furniture producers can use the higher portion (middle section) of the fir because it is relatively knot free and still considered high-grade wood. Thus, the furniture business gives the lower portion of the log to the plywood makers, in turn the plywood manufacturers turn over the somewhat lesser quality wood to the lumber producers.

trained to cut the top and middle of the tree so that it could be divisible into 8-foot lengths—the standard size to fit into the plywood mill. In the new mill pond as visualized by plant layout engineers, men would not be needed to jab logs into position with their sharp pike poles but remote-controlled water jets would nudge the logs into the chutes. Although difficult to visualize production flow at this time, time and motion study indicates that by standardizing the diameter of logs it would be possible to calculate economical runs provided that each lot contained equal-dimensioned logs. The company would probably acquire as few shallow clear logs as possible and would favor deep clear peelers, because a substantial amount of time is usually lost in changing from one kind of log to the other. Some engineers suggested a device which would preposition a log to fall into place as soon as the previous one was used up. It would work on the same principle as the cigarette automat: when the coin opens the bottom, one packet of cigarettes falls out and another automatically takes its place.

Assuming 8-foot standard logs, the estimated production capacities of work stations or groups of work stations, starting with debarking, are as follows:

Debarker, 3 to 4 minutes per log.

Peeler lathe's operation time depends on the diameter of the log. The machine can cut 50% more veneer per hour from cooked than from cold logs. From hot logs, spun against the blade, 1000 feet of veneer ribbon can be cut per hour.

Drying can be easily regulated. It can take place on a moving belt while moving to the gluing department where air or heat drying with the help of lamps can be applied.

Gluing can be almost automatic. A spray gun nozzle blowing glue over the surface would operate at a steady rate as the conveyor belt moved the veneer. Thus, cutting, drying, and gluing would lend themselves to a perfect synchronization.

From here on continuity of production would have serious limitations. Production must therefore branch out to make several different plywood products. Some branching out can start right at the cutting operation. Rotary cutting with a lathe could be replaced with a slicing machine and veneer could be sliced or sawed by a rotary saw. This would be used where the company produced a small quantity of special type of veneer for the furniture industry. Since 90% of the plywood is for buildings, not furniture, small-scale operations branching out as indicated above could accomplish company goals without disrupting operations of the main production line. Thus, skillful arrangement of veneer strips made in this sub-branch would go to an assembly department. Neither pressing nor assembly lends itself to standardization as far as furniture panels of this kind are concerned, because pressing time depends largely on 1) the type of glue used and 2) the thickness of the panels.

Therefore, a compromise production line is suggested, Fig. 3. As the figure illustrates, the first four operations are the same for all products. Veneer making, however, is divided into three different cutters: a) rotary cutting (90% of panels are done this way), b) the special type of plywood used in the furniture industry is either sliced or c) sawed. It is thought advisable to drop production of furniture panels and specialize in plywood panels used in building construction only. This would reduce gluing to a simple automatic operation (one glue would be used and it would be applied automatically as the veneer passed below a nozzle). Since assembly of (a) is simple, it is advisable to drop (b) and (c) types of veneer, which require careful assembling of wood patterns to develop eccentricities of figure and grain. If only (a) is produced, pressing can also be standardized. Since building construction panels are of standard size, preparatory work could be reduced to simple standardized dimensioning.

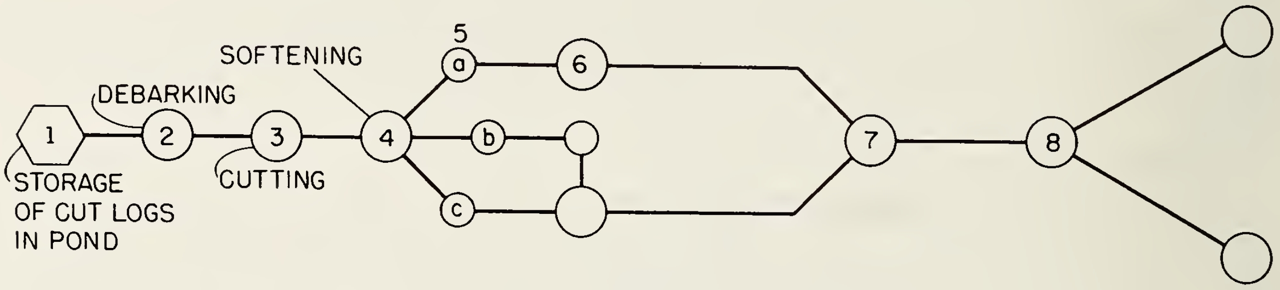


FIG. 3

Since the plan had not been presented as yet to headquarters, engineering personnel had a great deal of leeway developing production ideas acceptable to both Minnesota Pulp Manufacturing and the Paper Mills Alliance, Inc., as the parent organizations.

Questions. The student is reminded that before continuous production can be instituted certain conditions must be present. By checking the presence of these conditions students should be able to state whether it is feasible to install continuous production. Since the problem in itself has been in existence, the student should check the causes and ascertain whether management of the company looked for the solution in the right direction. Once this has been acknowledged or disproved, further analysis of the problem is warranted.

1. What are the symptoms indicating that the company with the present plant layout and operational facilities cannot operate profitably?
2. List the causes for these symptoms.
3. Does the company's approach seem to be in line with your way of thinking as far as eliminating the cause or causes is concerned?
4. To ascertain the correctness of your suggested solution to Question 3, check whether it is feasible by listing the factors indicating that it is.
5. If you agree with engineers over installing large-scale production, try to determine whether the proposed output capacity, break-even point, and

cost structure are correct. To accomplish this, draw up a break-even chart a) for the present set-up and b) for the proposed plant.

6. Determine the plant layout possibilities as suggested by the plant layout people. The general idea has been presented on p. 367 along with the time study data. Check them and indicate the number of minutes at which the production line must be synchronized.

7. Draw up a plant layout diagram under the assumption that river or lake transportation comes from the east and the railroad facilities from the west. Storage pond and debarking facilities are connected with a waterways transportation.

8. Support your plant layout ideas by stating why they are feasible and point out some of the probable shortcomings and expected difficulties.

9. With your knowledge of the case of the Paper Mill Alliance, Inc. answer the following questions: a) Do you think that it is in the interest of Paper Mills Alliance, Inc. to expand the Plywood Division of Minnesota Pulp Manufacturing Company? b) Do you think that it is in the interest of Paper Mills Alliance, Inc. to retain the Minnesota Pulp Manufacturing Company—including its Plywood Division—under the reorganization plan?

8-3. THE FORD MOTOR COMPANY

The Ford Motor Company is one of the three largest manufacturers of passenger cars and trucks for industrial uses. The company is engaged in the fabrication of parts as well as assembly work. Its assembly plants are located in strategic points throughout the country where production of the Falcon, Ford, Mercury, and Lincoln cars and individual models thereof takes place. Since these cars are structurally different from one another, some minor variations in the assembly method are bound to exist. However, basically all assembly work is similar.[7]

Figure 1 shows in simplified form how a car is put together at a Ford assembly plant. Parts from manufacturing plants are unloaded from freight cars into storage areas like those shown at top left. From there they move on to the various subassembly lines which feed into the final assembly line. The body line, which twists back and forth across the top part of this floor plan, is much the longest, taking 8 hours 38 minutes from the first welding jig to the body drop, where the body joins the chassis on the final line. The labels along each line show where some of the parts go on, but certain complications, such as special paint booths for two-tone cars and special fixtures for truck as-

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[7] The customary practice is that dealers turn over to the assembly plant blanket orders based on anticipated customer desires. Thus, the first cars coming off the production line are not based on specific customer requirements. A few weeks later, however, when the production line has been in operation for some time, dealers ask for specific styles, colors, accessories, and alternate parts. The amount of time between the date of order and the date of delivery depends primarily on the backlog of dealer orders in view of the fact that the capacity of the production line is limited.

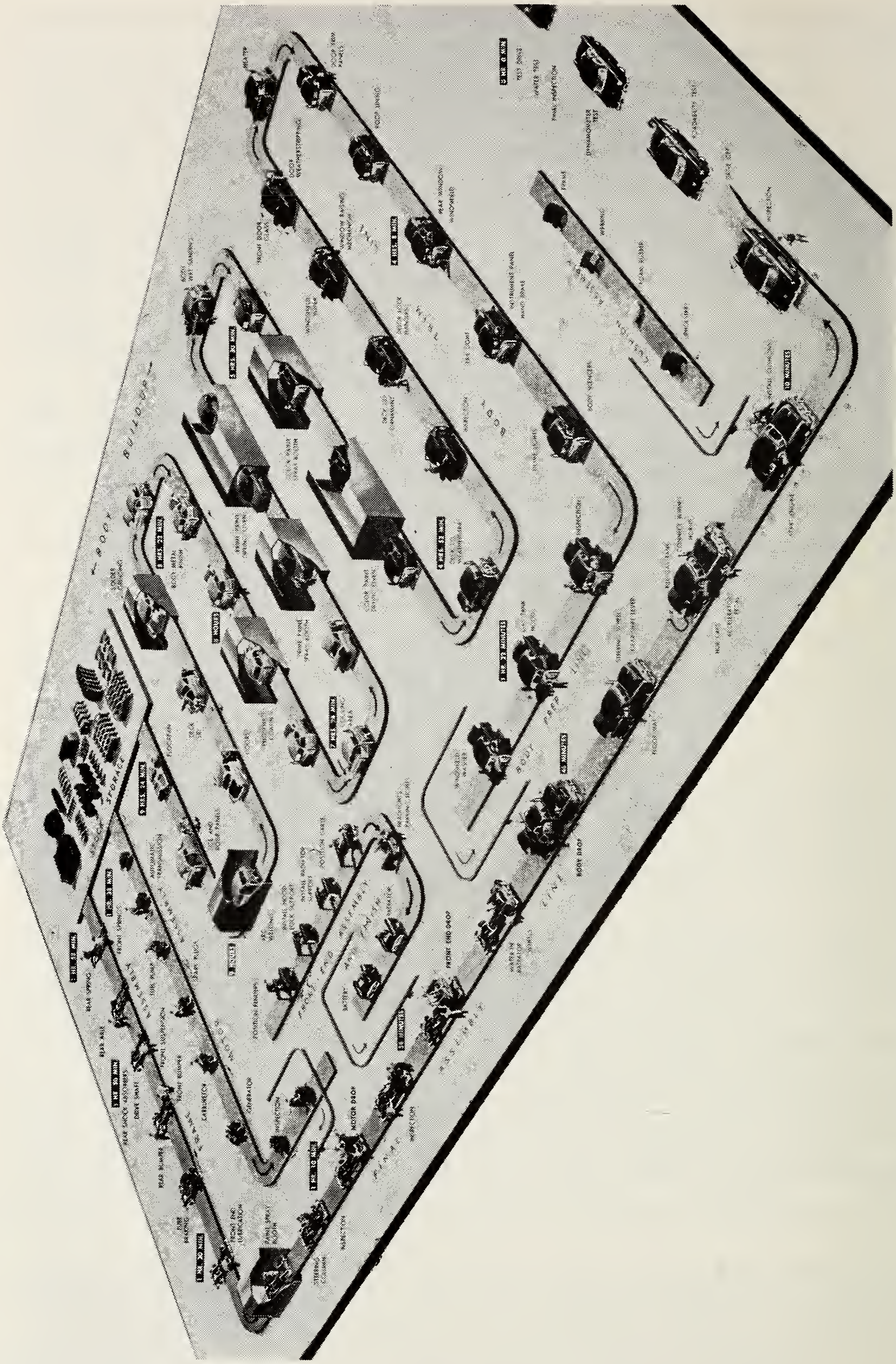

FIG. 1. Plant layout for assembling cars. (Courtesy of the Ford Motor Co.)

sembly, have been omitted. The black flags show the number of minutes required from these points to the drive-off station at the end of the assembly process. (Thus, the engine block starts its journey down the motor assembly line just 1 hour 38 minutes before it will be driven off the end of the final line; it drops on to the chassis 70 minutes before drive-off.) On the final line, stretching 803 feet across the near end of the floor, it takes just 87 minutes to turn the chassis at the far left into the finished car which drives off at right.

To set up this assembly line a great deal of engineering time was invested. Finally, however, a perfect flow of production was developed even though the company produces on the same assembly line deluxe, standard, convertible, two-door, and four-door sedans of several Ford Motor Company brand names. The production flows smoothly, and in the experience of the company delays are almost nonexistent. Some of the operations are shown in Fig. 2. When all the work stations are supplied with cars in process (that is, the production line is flooded), it is possible to state how many cars will come off the assembly line at the end of the day. This is not an accident but the result of careful process engineering, plant layout, and time and motion studies which ascertained operation times and stations so carefully that the various production stations were perfectly synchronized with one another.

Questions. The student will notice that the case study of the Ford Motor Company does not contain problems to be found and to be solved because it must be apparent that to set up an assembly line of such a complicated nature, the student would require a great deal more technical and practical knowledge. Therefore, the following questions are formulated so that the student can, in retrospect, go through the thinking processes which might have preceded the plant layout presented in Fig. 1. Thus, we are not interested that the student displays originality, merely that he reproduces certain charts and certain basic calculations which might have preceded the actual pilot run and lead to a finalized production line.

1. Draw up a process chart by using the following symbols:

◯ operation, ○ movement, ◇ inspection, △ storage.

2. On the basis of the information on time requirement, determine the speed with which the assembly line moves and state the production capacity of the line.

3. Since on the same production line several slightly different cars are being produced, show on the process sheet the branching out of the assembly process as well as the river-like flow of subassemblies toward the major assemblies and the feeder assemblies toward the subassemblies. In other words, determine the total production setup on a process chart by following up the possible flow of the product toward its completion.

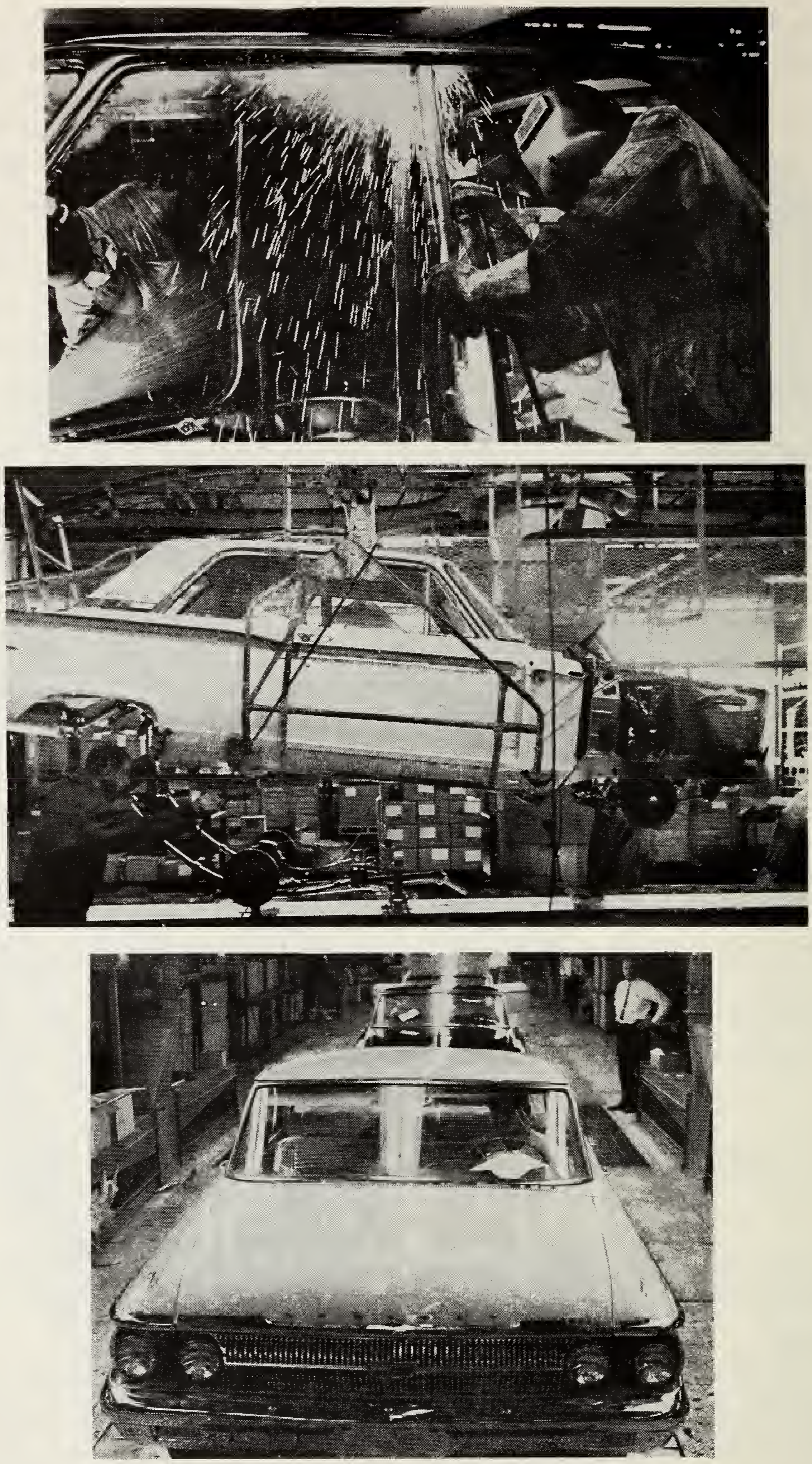

Fig. 2. Some of the operations in car assembly. (Courtesy of the Ford Motor Co.)

4. Do you agree or disagree with the plant layout arrangement as far as the assembly line of the Ford Motor Company is concerned? State your disagreement or, if you agree with the plant layout arrangement, support your statement by indicating why you agree with the production process as depicted by Fig. 1.

5. Take a pencil and show with numbers and letters, such as 1a, 2a, 2b, etc., where in the production line the following items will, in your opinion or observation, enter into the assembly of the automobile:

a. Sheet-metal stampings (fenders, radiator grille, hood, rear axle housing)

b. Finished parts (valves, connecting rod bearings, tires, fan belt)

c. Finished subassemblies (chassis frame, muffler, clutch, thermostat, speedometer, head and tail lamps, shock absorber, generator)

d. Finished subunits (horns, wheels, radio, battery, bumpers).

chapter 9

Control Methods

TOOLS OF PRODUCTION PLANNING

The term "tools of production planning" referred to in this chapter means primarily charts. Charts can be very useful in production control work because of their ability to depict production relationships visually, thereby permitting simultaneous consideration of several relevant elements of a production problem. Although charts are able to depict only two or three elements, sometimes it might be necessary to consider more elements than that. Charts are quite enough to show how a change in one of the several elements of production necessitates corresponding changes in some other elements. If more information is needed, recourse may be had to mathematical techniques (see Chapter 15).

A chart for production control work can be compared to a seating chart used by theaters to show which seats are open at any given time for any given performance. A seating chart permits a selective sale of tickets and helps in accommodating customer desires and may look somewhat like the chart shown in Fig. 9-1. The ticket clerk can quickly state which seats are still free or give other information to customers. Obviously, a separate chart must be used for each performance. The same thing is true of charts used in production control work. Different purposes, just as different performances, will require differently constructed charts. Thus, for example, the chart used for machine loading will indicate the machines vertically and the time during which those machines are occupied horizontally. A machine loading chart is shown in Fig. 9-2. This chart indicates that machines A and C

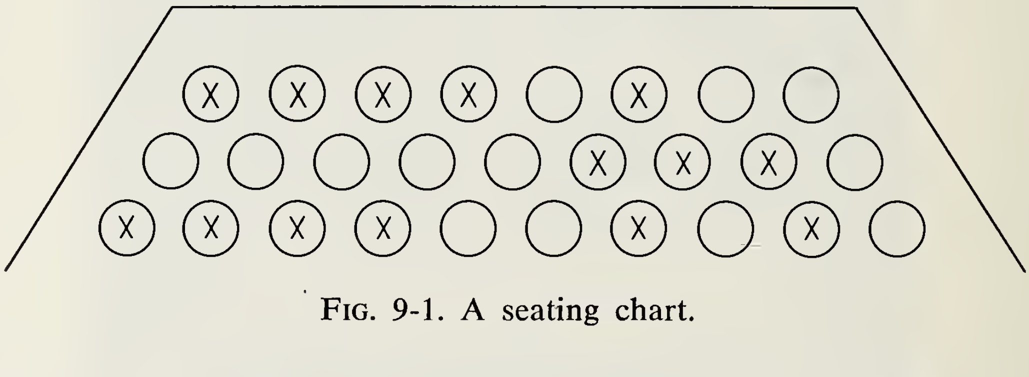

FIG. 9-1. A seating chart.

are busy on the first two days of the month and that B and C are busy on the third and fourth days or longer. A third element, namely, with what orders they are busy, should also be shown on the chart. This can be done by merely writing the customer's name or the order number into the particular block. In other words, by improvising, the chart can be used to give quite compact information about orders and relate them to the available time on given machines on any specific date (see machine C in Fig. 9-2).

Charts are better than mere records because nothing is overlooked. Of course, the information appearing on charts was transferred from written records. While a chart does not eliminate the necessity for record keeping, it will facilitate contemplation of both overall and localized production plans. If the chart is well designed, it is capable indeed of indicating what it purports to indicate. With the help of the chart the planner can therefore try out several alternative plans and see the effects of each contemplated action on overall plant operations. The chart, then, in a sense permits a preview of possible outcome of contemplated actions, in addition to serving as a compact source of relevant information.

	DAYS OF THE MONTH																							
MACHINES	1	2	3	4	5	8	9	10	11	12	15	16	17	18	19	22	23	24	25	26	27	28	29	30
A	▨	▨				▨	▨			▨					▨	▨	▨	▨						
B			▨	▨				▨	▨			▨	▨											
C	▨	CHRYSLER B-22						▨						▨	▨	▨	▨	▨						

FIG. 9-2. A machine loading chart.

Production is pretty much like a military operation. Just as military strategy must be carefully planned and depicted on maps to indicate which group will do what at any given time, so production must be planned. In military planning, the time factors are related to the number of troops; furthermore, supporting units are related to one another in terms of both strength and time. In the production situation several orders are related to one another in pretty much the same manner. For example, each of two orders will possibly require the use of the same production equipment. Since two orders cannot be assigned to the same machine at the same time, it is apparent that the time available on the machine must be apportioned on the basis of some desirable schedule. Schedules could not be developed much easier than with the help of visual charts.

Production charting has, of course, some advantages over the military charting in that most factors which affect production are predictable except for the possibility of a machine breakdown or other unforeseen event. But the unexpected will require a quick reshuffling of plans in the same manner that a breakthrough or unexpected deployment of enemy forces would require a swift reformulation of military plans. In other words, the chart may become invalid unless it is adjusted for sudden production changes such as order cancellation, replacing less important orders with a rush order, working on something else because of developing shortages in raw materials, or late arrival of components from outside suppliers. Furthermore, charts may help in keeping track of production happenings. When customer inquiries come in, it is relatively simple to locate the order and to determine its status, provided, of course, that someone has updated the chart as the situation has changed.

All in all, charts help to systematize the whole production planning process and simplify the task of describing the various problem areas and their intricate interrelationships. It must be apparent that new orders, as they come in, must be fitted into the existing production situation. Although production time on machinery is not always available when needed, the planner can, if necessary, make the machine available by shifting the various work assignments in light of the capacity needed to carry out production work on a new order.

In plants where records are not kept or where nothing is in writing, production problems can develop. But even if they are kept, records frequently are not updated. When raw material runs out at one workbench but is still available at another one, it is easy to rob the second to keep the first operating. But failure to record the shift in the use of the material might precipitate future production problems of greater magnitude than the original shortage. Of course, when charts are used, the same thing can happen, but charts are usually so designed that certain records are kept. These records are initially on cards and forms and are transferred to the charts. Thus, the paper-work flow is usually related to the charting system. Paper-work flow and charts together form the core of the production planning system in any company.

Charts can be designed for various purposes. Basically, planners use production as well as inventory control charts to determine when orders must and can be started in various departments in order to close them out at predetermined dates. Because production times, the number of operations, and the sequence of operations vary in the same way that lead times and delivery requirements vary, it is often difficult to decide when the operation that initiates production must take place if everything is to be ready when needed. The planner must evidently develop production time schedules so carefully that, in spite of the complicated route a product might take during its production, no bottlenecks or conflicts will develop. In a job shop, where several products may make use of the same equipment, time must be so precisely allocated that no two jobs are ever assigned to the same machine at the same time. Delivery commitments must always be met and also the product should not be produced too far ahead of time, so it is essential to preplan every move with extreme care. Both delays and premature completions can be very costly to the manufacturer. Late shipments cause customer dissatisfaction and, occasionally, the payment of penalties specified in the contract. Also, an attempt to prevent late shipment might involve overtime work and pay. Production ahead of time could lead to added storage costs and expose the product to damage or obsolescence. Also, the customer might cancel the order or call for redesign of a part during what should be a reasonable time. In other words, the producer should not be eager to finish his orders faster than absolutely necessary; more cost than possible benefit is involved.

To prevent delays, or to accommodate rush orders, prior commitments cannot be ignored. That is, one customer can not be given preference over another. Thus, use of charts will help to fit into the production program a new order, for instance, without shortchanging any other customer. A reliable supplier is always accurate in his shipments, which implies that he always has an up-to-date plan; this will also permit him to keep his costs always at a minimum. Without charting of production, this would be nearly impossible.

It is therefore the essence of accurate planning that all factors are looked upon in relationship to all other factors. Since charts are depositories of relevant information, they are capable of warning the planner about possible conflicts and difficulties. Thus, if the charts—usually more than one is involved in a production decision—conclusively indicate that a customer's order cannot possibly be completed in accordance with the delivery requirement, the company should not even accept the order. It is neither honest nor sensible to accept an order which the company knows at the outset to be impossible to execute.

Because the charting system shows visually what a company can or cannot do, it is considered by many to be better than an electronic data-processing machine. While the computer can manipulate data in the same manner that the planner can with his charts, no computer can illustrate its answers. Except for the necessary computations, the chart can abstract information in the same manner that a computer can, and, in addition, it can provide a picture of the situation as a whole. A difficulty forecast by the chart can force management to solve a problem today which could not be solved tomorrow. A computer cannot quite do this. In production planning, any possible obstacle must be located in advance so that a solution can be found before trouble develops. In other words, one must be reasonably sure of a trouble-free passage when a river is to be crossed.

The chart permits exploring different ideas in that several actions can be tried and the outcome tested. It should be remembered that it is easy to transport materials from one machine to another on paper; it is considerably more difficult to do so in reality. The chart is a quite reliable substitute for the reality of production, and the action that appears to be the best one can be selected before it is physically tried. The chart is thus akin to a road map used by a motorist planning a tour of the country. On the map he can find his destinations and visualize all the routes available for his trip.

The plan sets the stage for a whole series of actions in the production shop in the sense that it not only defines the goal but implements it with a feasible course of action. Because of the feasibility of preplanned actions, control can also be better achieved.

To be valuable, production plans must be feasible; therefore, the planner must work with reliable facts. However sound the plan might be, it cannot work if it is based on false premises. The facts used in the planning process are time study data, equipment capabilities, order sizes, and delivery requirements. Even though the possibility of machine breakdown is also a factor, the rule is to plan only with foreseeable and concrete factors. It is considerably more fruitful to reshuffle the plans when a breakdown actually occurs than to make the plans so loose that every contingency is accounted for. If it is loose, the plan could not ordinarily fulfill its purpose of making production efficient. When a breakdown occurs, the plan is obviously automatically out of adjustment. The advantage of tight and accurate scheduling, however, is that, until a breakdown occurs, everything should go strictly according to plan. After making all adjustments necessitated by the breakdown, the plan will again control production. A change in the situation naturally requires rearranging and updating the charts; but once that is done, the charts will reveal any difficulty that might arise as a result of the change. The value of the realization at an early date that, because of a specific breakdown, it is impossible to meet a delivery commitment cannot be overestimated. Since the original plan no longer holds true and must be reshuffled, the customer must be informed and given a chance to modify his position. If the delivery date cannot possibly be postponed, the company must make suitable arrangements to accommodate the customer. If the customer agrees to a new delivery date, a new work load allocation plan must be worked out so that production will indeed be accomplished on that date. The chart tends to show approaching "danger" far ahead of time; hence, it permits a timely rearrangement. What probably is more significant is that appropriate changes can be made without substantially disturbing the intricate interrelationships. When the production plan for product A must be changed and the change is bound to cause changes in the manufacture of items B, C, and D, necessary rearrangements can be made to prevent the development of bottlenecks. If all productive actions are properly charted, the necessary adjustment to changing circumstances can be made relatively fast. Occasionally, the reshuffling of plans merely consists of pushing up visual markers on a chart to accommodate recurrent changes. In brief, graphic representation of contemplated actions can tell at a glance:

1. Scheduled starting and completion dates on all orders (present and future) in perfect relationship to one another.
2. The machinery, the department, and the type of work which are affected by each new order and the effect of each change on future, as well as past, production plans.
3. The progress each order makes against a predetermined plan.
4. The allocation of available plant capacity irrespective of the nature of production (a production line, a job shop, or a critical department).
5. The availability of raw materials and the size of in-process inventories at any given time.

It must be emphasized that "charting" does not imply the use of only a single chart. A new order must often be placed on a large number of different charts. Each chart will help in the planning of only certain phases of production. If the use of a given machine is contemplated at any given time, a load chart must be consulted; if the availability of certain raw or in-process material is to be ascertained, inventory control charts must be consulted; if the whereabouts of a given order must be checked, a progress chart must be consulted. In other words, charting is simple enough, but a series of charts must be used in order to determine all the facts necessary to establish feasible plans. Charts are evidently useful in comparing simple as well as complex magnitudes and can show variations in the component parts and in totals, in both absolute and relative terms.

THE GANTT CHART

The principles of Gantt charting were laid down by Henry Gantt, a pioneer in the scientific management movement. Although Gantt was not the first to use charts to illustrate production situations, he was among the first to put his ideas in writing.

The applicability of a chart varies, but with minor alterations the same chart can be used for different planning purposes. Although charting is of only secondary importance in continuous production because the production process is built into the plant layout, Gantt charts or their derivatives are still useful for visualizing certain phases of continuous production. In intermittent and often in repetitive production, on the other hand, charts are invaluable, particularly when there is severe competition which may be coupled with a profit squeeze or when demand exceeds supply. Supply is limited by the capacity of plant facilities, and the chart, by revealing the production situation, permits a better utilization of men and machines. This means, of course, reduction in costs and ability to set competitive prices on the one hand and raising the output without adding to productive capacity on the other.

With Gantt charts, it is possible to set realistic delivery dates. When salesmen, for instance, phone the home office to determine when a delivery can be made, an accurate and reliable answer can be given within a relatively short period of time. Since Gantt charts permit a look into the future, they eliminate at the outset some of the difficulties which can result from haphazard scheduling and indiscriminate acceptance of orders, and they help prevent cancellations and customer dissatisfaction.

In the final analysis, charting techniques tend to facilitate planning and to enable selecting feasible production actions. By the mental processes of planning, production decisions would, by necessity, be disjointed and piecemeal; with Gantt charting, however, every new decision is made in accordance with the overall production program. A Gantt chart is something like an orbiting satellite which permits looking at the earth, and every part of it, almost simultaneously.

The various purposes of Gantt charting are:

1. Departmental work load charting
2. Machine load charting
3. Progress charting
4. Inventory and stock levels charting
5. Charting the master program (master schedule)
6. In-process inventory charting
7. PERT system planning and control charting

A brief summary of each of these charting methods is given here; prior to a more elaborate explanation of the how-to of charting. As said before, in some production organizations, all of the above charts are used; whereas in others, only some of them are used.

Departmental work load charts are particularly useful in plants that have a physically fixed capacity. In such plants, the allocation of a given load leaves a known amount of capacity still open (for example, containers, tanks, and vats can hold only a given amount of material). The output in some other plants may depend on the number of hours worked: a department can turn out only a given number of units during an 8-hour day. In most production situations of the intermittent job shop or the repetitive production shop variety, allocation of departmental work loads is not quite as simple because the capacity may be unknown until time study data are available. The capacity of the plant, department, or machine depends on the time required to complete a given product. Since the completion time of each product might be different, the plant capacity depends largely on the item to be produced.

A *machine load chart* is used primarily in job shops to show the availability of equipment for different operations on various contracts. It helps the planner to visualize the occupancy of a machine with different job assignments and to make an appropriate decision relative to a new order.

It also helps to allocate work loads among machines in accordance with production sequences. Obviously, assignment of operations out of phase is usually not possible because each operation tends to depend on all preceding operations. The operations must be assigned in an appropriate sequence.

Allocating operations among a limited number of machines in intermittent production is a rather delicate task, particularly because divergent delivery commitments, in addition to a number of other factors, must be considered. Unless a well-designed chart accurately depicts when a machine is open or busy, it is nearly impossible to plan an orderly flow of production and the completion of orders without conflicts in the use of equipment. Of course, if the total backlog of work exceeds the capacity of the machine, it is physically impossible to do the work no matter how well the equipment is scheduled. What usually happens, however, is that equipment tends to stand idle during a portion of the day. By proper scheduling, the use of equipment can be evened out and its productive time enhanced. But, if on a specific piece of equipment 100 man-hours of labor is needed to complete a specific operation on an order and only 50 man-hours is available, then other production plans must be made. The advantage of charting is that such facts "become visible"; in this case subcontracting or some other arrangement must be made for 50 man-hours of machine time. Without a load chart, it would be quite difficult to see how a new order can be fitted into an already busy production program.

Progress chart is the name given to a presentation of the production program in the form of a time table. It shows the position of an order or part of an order relative to the production program as a whole. But what is probably more important, it shows the advancement toward completion of the various production plans, and it is therefore used to advantage in intermittent and sometimes in repetitive production. When a customer inquires about the progress of his order, a quick look at the chart will give the answer. Because any company can encounter difficulties, a customer is quite frequently forced to ask that the completion of his order be accelerated or slowed down. If up-to-date production charts are available, the supplier can give his customer a precise report on the status of his order so that a new arrangement can be worked out. In addition, since it is a graphic record of accepted, scheduled, and constantly progressing orders in relationship to one another, the progress chart is a replica of the "production schedule" of a job shop on paper.

Depending on the company's method of charting its production progress, a good or a bad overall picture can be gained. For the sake of simplicity, often only the finishing dates are stated on the progress chart. This tends to be sufficient in expediting work. Thus, if at any time the production program is out of order, the chart immediately indicates the danger. Once the need for corrective action is known, the difficulty can be investigated and appropriate action can be taken before it is too late to make a costwise and otherwise sensible adjustment. It is vital that management know at all times whether the various orders are progressing on schedule, because a delayed movement of an item can cause costly overtime work, late shipment, or penalty payment.

Of course, to serve their purpose, progress charts must be religiously maintained and updated by daily, or even hourly, postings. For this reason, there must be a constant communication between the shop and the production control office. When an operation has been completed on a part, the information is reported by teletype, telautograph, intercommunication radiotelephone, shop cards, or any other convenient means. The information will, in turn, be transferred to the chart (follow-up line). This is akin to charting military operations by pinning little flags at the positions which have already been taken. The progress chart shows at a glance where the part or order should be, where it is, and where it is scheduled to be in the future. In other words, it shows actual versus scheduled performance.

Inventory and stock control charts are especially valuable in either repetitive or continuous production. The chart has some limitation in that it must be used along with other charts in order to be meaningful. In a sense, these charts furnish information for production scheduling purposes. Either the in-process or the stock control chart is needed when the making of parts must be synchronized with the movement of the production line, which in turn depends on the availability of parts and components. Evidently, assembly of an item for which parts are in short supply might be postponed in favor of another for which everything is available. Reliable scheduling would be impossible without precise information about the availability of raw materials or components. Although inventory records containing the same information can fulfill the same purpose, the advantage of charts lies in the speed with which they can convey needed information. To gain information about the availability of materials by using charts, no mental juggling or further calculation is needed; all the relevant data are represented by a self-explanatory picture. Of course, the requirement still is that the chart be religiously updated. Otherwise, it loses its validity.

The inventory control charts, particularly the in-process inventory chart, does a great deal more than keep track of materials in process. Indeed, it is the basis for repetitive production scheduling (see Chapter 12).

The PERT system, like most of the charting systems, uses time as a common denominator to reflect the factors influencing success—time, resource application, and performance information. *PERT*—for program evaluation review technique—can be used in special project planning. Events, activities, and factors are interrelated to one another and, in absence of computers, can be shown on Gantt charts in the same manner as master schedules. However, in view of the fact that several factors may be worked on simultaneously, overlap-type scheduling may represent best the system in chart form. Generally speaking, the advantage of the *PERT* system is that when performance times are not available for given activities (activities for which there is no time study or other reliable measurement), such performance times are computed mathematically through the use of statistics. Thus, the use of the probability distribution of the times involved in performing the activity rather than the charting system itself is new.[1] As said before, by using the performance times ascertained by statistical computations, the program can be depicted on a master chart where the horizontal line will represent the time factor and the vertical lines the activities. The interrelatedness of bar charts to one another can, in turn, depict the relationship between activities. Ordinarily, however, a computer is used.

Master scheduling is used when the same facilities are utilized for several items. The overall company production plan can be depicted on master load charts. Such charts bring the various departmental activities in relationship to one another. Departmental work loads are apportioned in such a manner that all work assignments are subordinated to the master production program.

Assuming that a machine shop is engaged in the fabricating-assembly type of production of items A, B, C, and D and has a contract with the military to deliver a given quantity of each item every month, an overall production plan must be set up to determine which department on which day of the month should produce which part or accomplish which specific task. The example in Fig. 9-3 is an oversimplified version of a more complicated master plan, but it is adequate to illustrate the use of charts to master-plan operations for several months. On this example chart, which is limited to three months, assembly is represented by solid black, the machine shop by diagonal shading, and the paint shop by dotted shading. On actual charts, which can explain many things without words, different colors would be used in place of shading. It should be noted that the planner must start his planning from the delivery date backward. Thus, one must start the plan with the assembly and must gage painting and the making of parts so that they become available as the assembly department needs them.

Figure 9-3 is the result of many hours of planning work. The planner, after careful consideration of many factors, had to determine which product should be started first, which second, and so on to attain the desired objectives. Then he had to determine the work loads on the basis of time study data, the available number of workdays per month, and the quantity

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[1] The time requirement is based on optimistic a, pessimistic b, and realistic c time estimates. Ultimately, time is arrived at by the use of the following formula:

$$T = \frac{a+b+(4\times c)}{6}$$

In other words, we add up four times c, plus a and b and divide the sum by 6.

of each of four products which can be produced. The capacity of the production line is usually known, and the assembly schedule (that is, the appropriate number of days) must be plotted on the chart. When production of item D has been completed, work will start on the assembly of item C and thereafter of items B and A.

The next step in this planning procedure is more complicated than the first one because the components of each product must be made available prior to start of the assembly process. On the assumption that each product consists of three components, it is essential to determine whether all parts can be completed sufficiently ahead of time that production at the assembly level is not held up. In other words, to maintain a relatively smooth flow of production, the availability of components must be assured. To determine starting dates to have things ready in time, recourse is had to the appropriate departmental work load charts, machine load charts, and often even to the various inventory control charts.

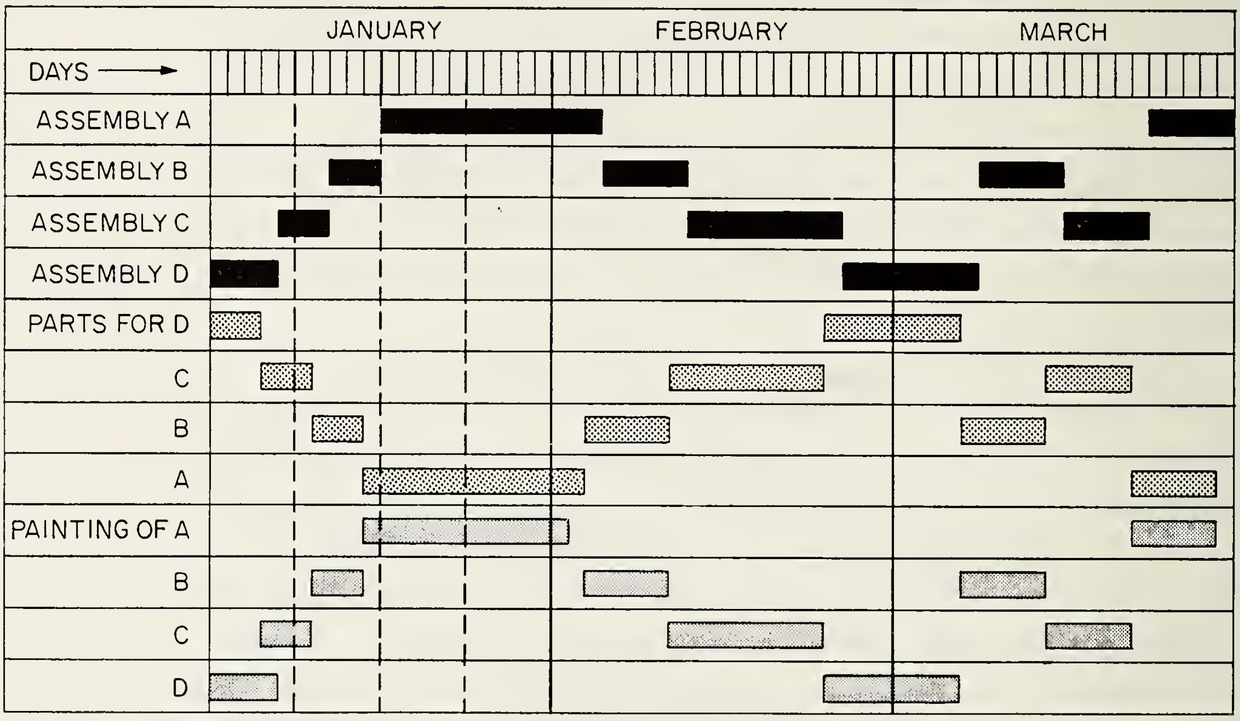

Fig. 9-3

At this point it is sufficient to learn that, before anything is plotted in Fig. 9-3, many other calculations of efficiency and economic lots are made with other planning tools and charts. Thus, by the time the information is transferred to the master planning chart, it is usually accurate; and all details are bound to fit into the master production program. The same thing is true, of course, so far as the paint shop work is concerned. The various manufacturing divisions must, by necessity, turn over the components they make to the paint shop; and evidently, before they are ready for assembly, parts and components must come out of the paint shop. Unless both the manufacturing divisions and the paint shop can complete the items in time, assembly cannot start as planned. Also, there is another element that must not be forgotten, namely, the arrival of purchased items. The deliveries of suppliers must accordingly also be synchronized with the overall master production program in the same manner as the deliveries from the company's own manufacturing divisions.

To calculate the work load for the paint shop, the general framework within which the plant can function has already been outlined. Therefore, the facts important to paint shop scheduling are largely known. If the daily output capacity of the paint shop operations has been determined by time study, it is easily possible to establish starting and finishing dates and schedule possible overtime work as required to accomplish all work necessary to keep the production line moving. The actual schedules can be read off the chart, Fig. 9-3.

It should be pointed out that, realistically speaking, not all parts are needed at once. Staggered delivery at the appropriate work station at the assembly line is often permissible as long as the items arrive before the assembly workers need them.

On the basis of the *master load chart* (master scheduling), it is possible to determine departmental production orders for each of the items to be produced during the next three months or more. Thus the master schedule, Table 9-1, can be written out and turned over to the proper superintendents and foremen. The student should go back to Fig. 9-3 and try to see how the starting and finishing dates contained in Table 9-1 were arrived at. The process of copying the information from the master chart should go on until all information in respect to every department has been copied. The chart is used by the planners, but the respective supervisory personnel receive only the information shown on Table 9-1 (that is, produce, by February 3, x number of A items).

TABLE 9-1

MASTER SCHEDULE
Department: Assembly

Item	Completion Date	Starting Date	Quantity
A	Feb. 3	Jan. 11	
B	Jan. 10	Jan. 8	
C	Jan. 7	Jan. 5	
D	Jan. 4	Jan. 1	

The chart in Fig. 9-3 would ordinarily be based on actual calender dates excluding Saturdays and holidays. The quantity column in Table 9-1 was not filled out because only the idea is illustrated. Based on the capacity, it is simple to fill in all necessary details. A realistic master schedule would resemble Table 9-2.

By looking at such a neat schedule, few people would realize the work which lies behind it; yet it is apparent that a great deal of time and effort must be spent to establish a reliable master program. A master schedule would usually be constructed for a period of 6 months or more. Of course, it is only a plan and any change will necessitate adjustment. The planner works with current production capacities, but when either an addition to facilities or a machine breakdown alters the output capacity, the master schedule must be revised. Also, a change in forecast sales will bring about corresponding revisions in plans.

An important advantage of charting the master schedule is that any sudden event, with all its ramifications, can be projected into the future. Thus, a significant change in January is bound to cause a corresponding change in March. Therefore, by looking at the chart one knows back in January the accompanying changes which presumably will occur in March. Accordingly, one can get in touch with customers or related production departments and work out solutions at once, long before the problem becomes insoluble. A customer who is notified about a possible delay several months in advance might have time to revamp his own production program or communicate with the prime contractor so that a possible delay can be accommodated.

TABLE 9-2

MASTER SCHEDULE

DEPARTMENT	PRODUCT	DATE		QUANTITY	REMARKS
		Start	Finish		
Assembly	D	1/1	1/4	400	Rec'd from paint
Assembly	C	5/1	1/7	300	Rec'd from paint
Assembly	B	1/8	1/10	300	Rec'd from paint
Assembly	A	1/11	2/3	1300	Rec'd from paint
M. shop	D	1/11	1/3	400	Give to paint
M. shop	C	1/4	1/6	300	Give to paint
M. shop	B	1/7	1/9	300	Give to paint
M. shop	A	1/10	2/2	1300	Give to paint

DEPARTMENTAL WORK LOAD CHART

In setting up a company's master schedule, recourse is often had to departmental work load charts. Although departmental work load charts have some limitations, they can be very useful. The limitations can be explained by saying that unless the departmental work (performance) capacity is fixed, the chart has no validity. The criteria of measurement of capacity must, of course, be known before this technique of planning can be applied. In a shirt manufacturing plant, all shirts go through the same manufacturing process and time per shirt does not substantially vary. Thus, the capacity of each department is known, within limits anyway. Thus, the buttonhole department can turn out *x* number of shirts buttonholed per hour, per day, and per month. A mere allocation of hours is adequate to determine the work output.

Departmental work load charts can be applied in process or "similar process" industries, where the company produces items recurrently and capacity is everywhere fixed. Where different products are made recurrently, the time study data per item might vary, but since the items are recurrently produced in batches or economic lots, it is possible to allocate so many hours of the machines in a department for a given purpose. In this case the departmental capacity is expressed in, say, 10,000 minutes per month. Depending on the performance time per economic lot quantity, the departmental capacity is blocked out for that purpose. In job shop operations this would not be possible because of the large variations of time standards from job to job, on the one hand, and the specific equipment requirements which depend on the nature of operations, on the other hand. The result is that a simple allocation of work loads is not possible. Since information on the needed production quantities is known from other sources, one can easily determine whether the department can handle a given type of work within the available time. The departmental work load chart, which would look like Fig. 9-4, reveals at a glance the capacity which is still available and the work with which departments are occupied. The empty space between allocation of departmental capacities might represent idle time, but it might also represent "waste" or "downtime" necessary to convert the department from one use to another. From the chart it is apparent that departments E, F, and G are poorly utilized. The production people might, consequently, advise the sales

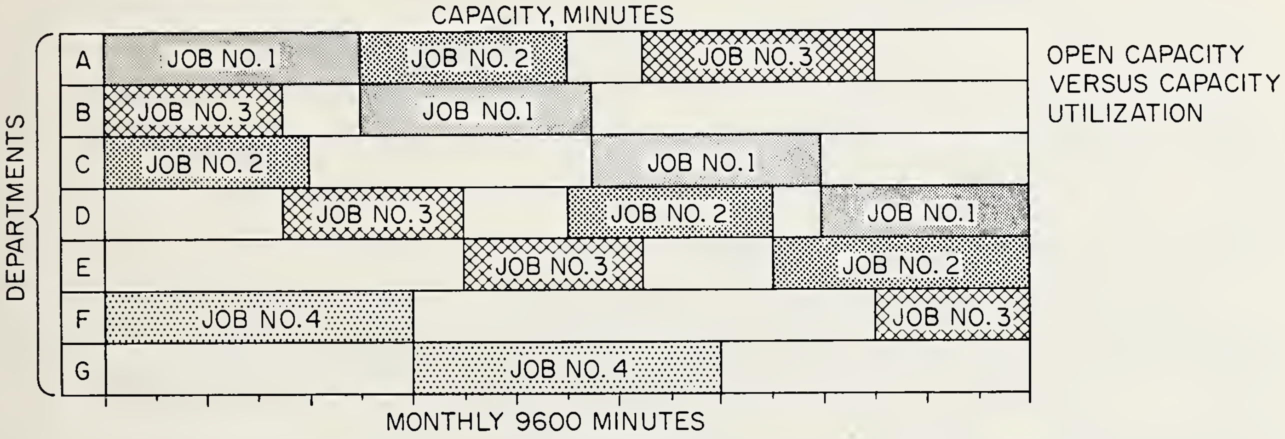

FIG. 9-4. A departmental work load chart.

department to push the sales of given products in order to find work for the unused departments.

Charts ordinarily illustrate one-shift operations, but they can be so constructed that they represent two- or three-shift operations. Although the distance on the chart probably remains the same, it can be calibrated differently. The same distance might, for instance, represent 9600 minutes (one-shift capacity), 19,200 minutes (two-shift capacity), or 28,800 minutes (three-shift capacity). Obviously, when plural shift capacity is depicted on the chart, the chart cannot be divided into calendar dates but must be divided into minutes of the two- or three-shift month.

While it is relatively simple to show the capacity of several shifts on the chart, it is difficult for planning purposes to illustrate one-shift operations with overtime work. Therefore, special notations must be made to illustrate overtime work.

As the following section will reveal, the method of charting machine loads is almost identical with the method of charting departmental work loads. While departmental work loads represent the output a department can handle, machine load charts depict the production that specific machines can handle during a given period of time.

THE MACHINE LOAD CHART

The machine load chart would be used extensively in intermittent job shops. Since in job shops the various orders take different paths through the shop, it is essential to know that various machines are or will become free in order to properly allocate the work load among machines. Knowing the general availability of a given equipment is not enough, however. The specific time when the machine is free is of equal importance, because the assignment of various operations to various machines must follow a predetermined and rigid sequence. Thus, prior to tapping, a hole must be drilled, and this sequence cannot be altered. Accordingly, the planner must be able to see on the chart whether or not two related machines are free in the appropriate time sequence. Obviously, the machine performing operation 1 must be free earlier than that performing operation 2. Unless the operations are interchangeable, the fact that a machine is free to perform operation 2, at the time for which operation 1 is planned, just does not matter.

The load chart illustrates the availability of machine time on given dates; it depicts the time duration of machine availability. Indeed, since the main objectives of job shop scheduling are orderly production and meeting delivery commitments, scheduling cannot be effective without such a visual aid. While the machine load chart is a simple device, it contains much information vital to the illustration of overall plant utilization: the day on which a machine will be available; the length of time it will be available; various possibilities for synchronization of operation sequences, etc. One thing which is ordinarily not shown on load charts is the setup time. It is possible, however, to remedy this shortcoming of the load chart by merely adding to the total operation time the approximate amount of time for setup. Thus if a job would tie down the machine for 2 hours and the setup time would take approximately 20 minutes, the total time requirement to perform the operation on this machine is considered not 2 hours, but 2 hours 20 minutes. This total time requirement must be determined, because what the planner wants to know in future scheduling work is the time when the machine will become available. And setup time ties down the machine in the same manner as actual operation. A typical load chart is illustrated in Fig. 9-5.

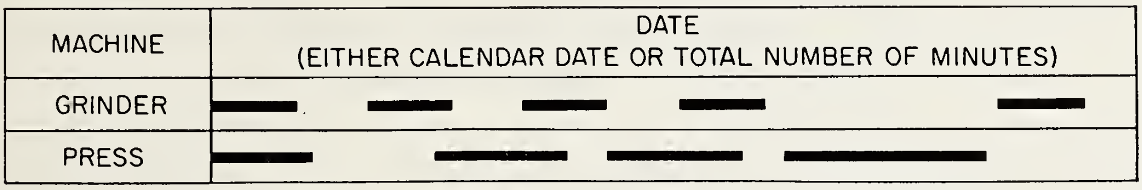

Fig. 9-5. A typical load chart.

To illustrate the use of a load chart, the assumption is made that a company has three different machines, namely: a milling machine (A), a drill press (B), and a welder (C). As the company accepts incoming orders and books them (that is, loads the machines), the load on the various machines appears as shown in Fig. 9-6. Apparently, machine A is free on Wednesday and Thursday in the first and second week of January; then again on Friday in the third week; on Monday, Tuesday, Wednesday, and Thursday during the fourth week of January; and during the first and second weeks of February. Machine B is open during the fourth week of January and the fourth week of February. Machine C can be assigned some work during the second week of January and the first and second weeks of February.

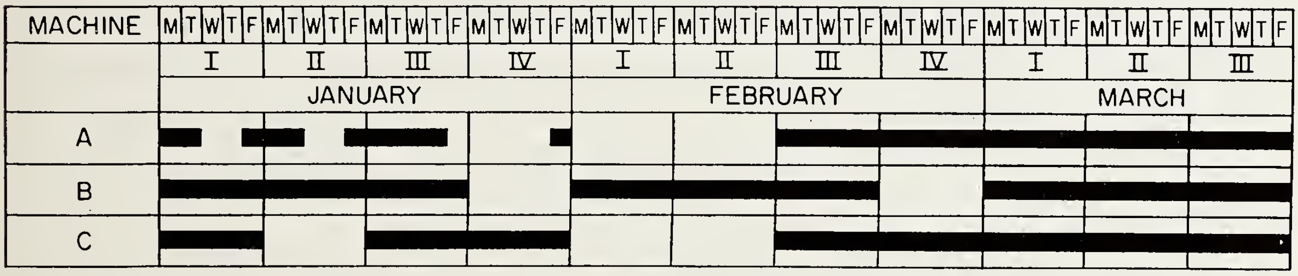

Fig. 9-6

Obviously, this chart is similar to the seating chart mentioned earlier, except that "when" and "how long" are also illustrated. Of course, to know how long a given operation will tie down a piece of equipment requires information about time standards on that machine. "When" to use the machine depends on delivery requirements and operation sequences.

Conflicts in the use of machines are often unavoidable. When a conflict is encountered, the planner must experiment with different production ideas until all orders were properly arranged in the time as well as operation sequence. If the chart indicates that the job in question cannot be completed in accordance with the delivery requirement, the customer must be given a chance to withdraw his order or to renegotiate a new delivery schedule which the company can meet. More will be said in Chapter 11 about the actual use of load charts.

THE PROGRESS CHART

To determine the production schedule, vacant machines must be found. When they are found, by means of the chart, the production decision can be made. In order to keep track of each order, the schedule that is finally arrived at must be transferred to another chart: the progress chart. The progress chart will contain all starting and finishing dates, or only all finishing dates, of every order or part and every individual operation. In most companies the plant does not bother posting the starting date but posts only the finishing date. The reason for this is that one is interested in the accomplishment of each operation rather than in the start of an operation. When too many data are contained on it, a chart becomes too complicated to serve its intended purpose.

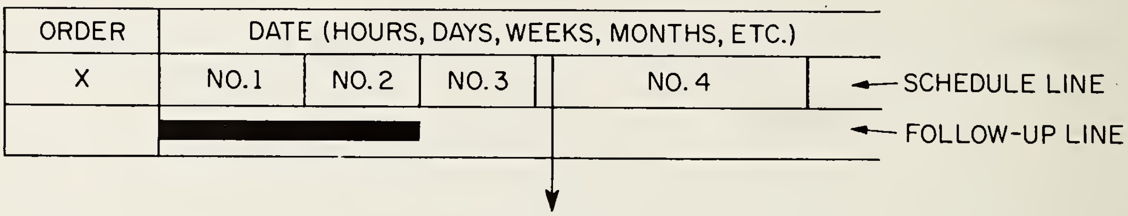

Fig. 9-7

If in the machine shop of a company part *x* must be processed by operations 1 to 4, cutting, filing, drilling, and tapping, this will appear on one horizontal date line. The progress chart differs from the load chart in that, in lieu of listing the equipment vertically, the order or part is listed on the first line. A second line is the follow-up line. In other words, the schedule is indicated on the first line and progress is indicated on the second line, as shown in Fig. 9-7. There is also a vertical line, the today line, which, by cutting across the horizontal time line, indicates the particular date. In order to use this chart with success, it is essential to move the "today line" to the right each day. Thus, the vertical line cutting across the schedule and progress lines will show whether an order is behind, ahead of, or on schedule. If the progress line falls to the left of the today line, it is necessary to investigate the delay and take remedial action. If the progress line and the today line coincide, the operation was performed according to schedule. Occasionally, the progress line will be found ahead of the today line, indicating that production is, for some reason or other, ahead of schedule. Thus, the progress chart illustrates both schedule and the progress made toward meeting the schedule.

In modern industrial enterprises, expeditors see to it that production is up to par. No matter how well plans are developed, something might go wrong. Delays, particularly when compounded, can destroy the value of the overall plan. For this reason, any difficulty that causes a delay must be resolved at the source and corrective action must immediately be taken in order to prevent other related departments and operations from being involved. The expeditors usually follow up the progress of orders with a progress chart. If the chart indicates that an item is behind schedule, as operation 3 in Fig. 9-7 is behind, the expeditor will immediately find out why.

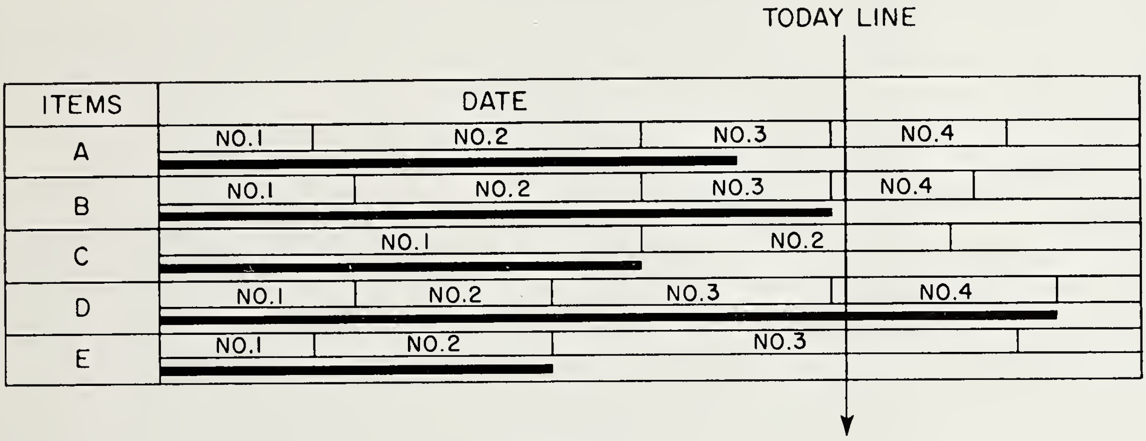

Fig. 9-8

The today line, as in Fig. 9-8, will always reveal whether an operation is on schedule. In Fig. 9-8 we see that items A, C, and E are behind schedule, B is on schedule, and D is ahead of schedule. At times it is difficult to see whether an operation is behind schedule, because most progress charts are so constructed that only completion rather than starting dates are shown. Both starting and finishing dates are sometimes shown in an effort to make the chart more useful, but any unnecessary information only complicates the chart. Sometimes, as shown for A, the line will be drawn when a lot is partially completed. In other instances, the line will not be drawn until the entire lot is completed. Careful checking is therefore necessary in order to ascertain whether E is indeed behind schedule. Expeditors know if something is behind and can check. In any event, it is important to keep the chart as simple as possible; if it becomes too cumbersome, it might not fulfill its purpose.

A modern version of the progress chart is the Produc-Trol board sold by the Wassell Organization, Inc. The basic principle in its use is the same as explained above; there is no need, however, for charting anything by hand. A board has a large number of two-row hole pairs into which pegs fit. Different colored pegs can represent different machines or departments. By placing a specific peg with a round, square, or triangular head into a hole in the first row corresponding to a preplanned starting or finishing date, the first row will indicate the production schedule as the item moves in the production process. The second row has a retractable string which will be advanced to indicate how far the operation has progressed. When an operation is performed, the progress line—the retractable cord—is placed directly under the peg representing that operation.[2]

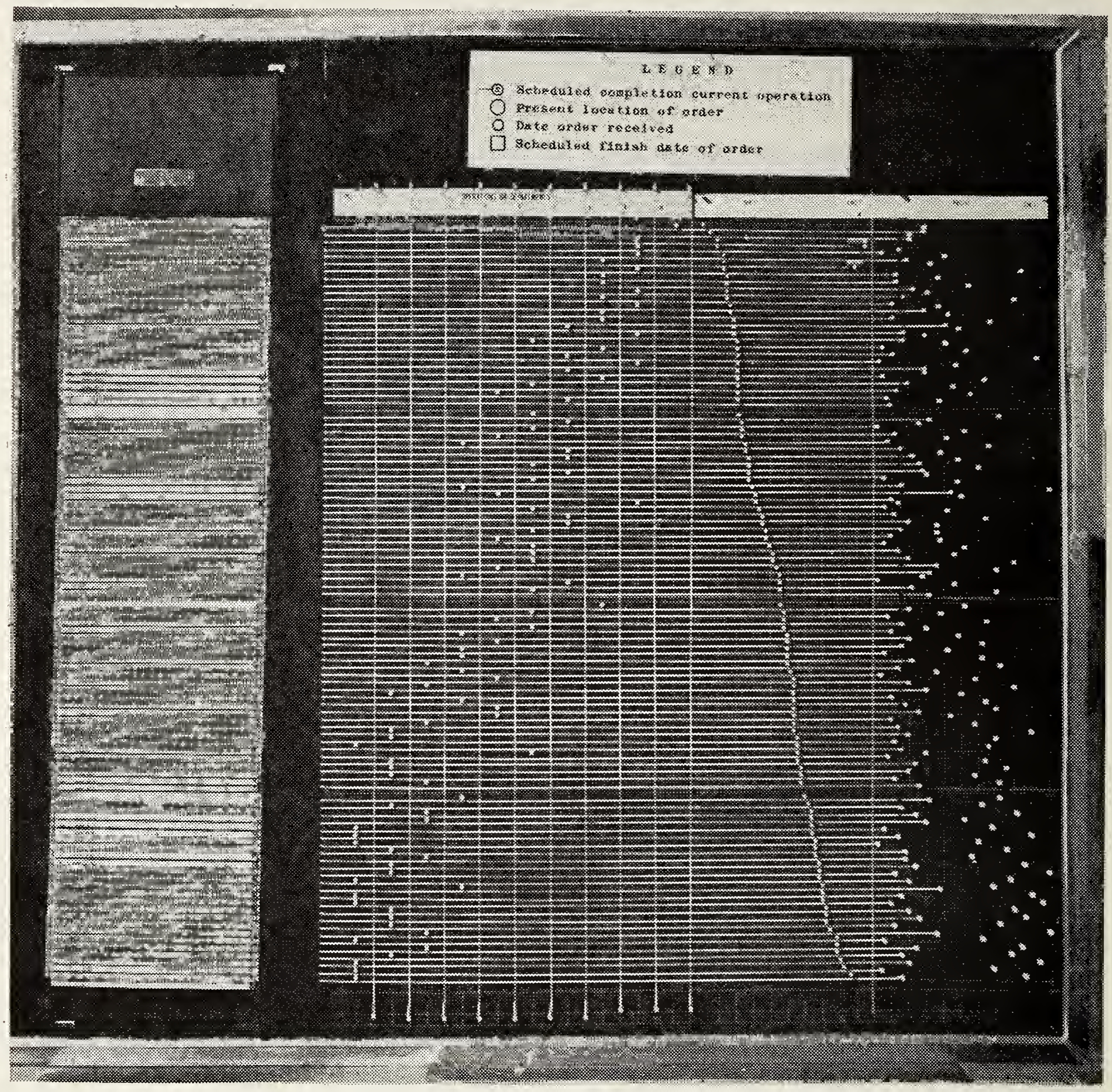
LEGEND
Scheduled completion current operation
Present location of order
Date order received
Scheduled finish date of order

FIG. 9-9. The Produc-Trol board. (Courtesy of Wassell Organization, Inc.)

Whether the operation is behind or ahead of schedule can be seen in the same manner as with the conventional chart. A vertical cord represents the today line. Any follow-up cord which falls behind the today line indicates that the operation is probably behind schedule. At any rate, it must be investigated. The Produc-Trol board, Fig. 9-9, should be studied carefully.

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[2] The manufacturer suggests that the follow-up cord be advanced once the operation is started, but doing so, in the author's opinion, can foster a false sense of security. Progress should be charted only when it has actually been made.

MATERIALS CONTROL CHARTS

Whenever production is being planned, one is concerned with availability of all the factors of production at the right time and place to meet production commitments. In this planning process the human production factor is not so much considered as the physical means of production: equipment time and raw materials. If these factors are placed at the disposal of labor, the chances are that production will be carried out. Thus, the task of the production planner is to determine the plan of action in light of availability of machinery and materials.

The load chart shows the availability of equipment, and the various materials control charts show the current status of raw materials. Without this kind of information, planning would—particularly in repetitive production—be in the abstract. Although men and machines are available, unless the necessary raw materials are also placed at the disposal of the worker, production cannot even begin.

The term "materials control" is interpreted in various ways. As far as production control work is concerned, materials control fulfills its function by assuring the presence of materials. In most instances, the materials control people worry about the cost and storage, but problems of that kind are incidental to the production control problem. From the production point of view the availability of enough materials to keep production moving and the number of in-process materials in different stages of production must be known. Hence, these charts should illustrate whether it is feasible to carry out the production program.

Since material and production control are closely related, record keeping is often lodged in the production control department. Thus, the charts we speak of are on display on the wall and the materials control as well as the production control men can take advantage of the information the charts contain.

THE INVENTORY CONTROL CHART

The first step in establishing an inventory control chart is determining what the horizontal and vertical lines on the chart will represent. The horizontal lines will usually denote the number of completed units of a given item. A continuous producer, making one standard item consisting of several standard parts, needs one chart only, but, of course, with several lines on it. A producer making several items (similar items) on the same production line must have a separate chart for each product with its component parts. The horizontal lines will denote the quantity available and the vertically listed items are components (the parts list) or the bill of materials in either a logical or an alphabetical order.

The second step is the posting of the information on the chart as changes occur. However, to avoid confusion and errors, a careful interpretation of facts is of considerable importance; otherwise, the chart loses its validity for the intended purpose.

Let us assume that the chart in Fig. 9-10 is one being used by a producer of automobiles. Thus, the horizontal lines would represent the number of completed passenger cars that can be assembled for shipment from the parts available. The vertically listed items indicate a few representative parts making up an automobile. The parts, listed as A, B, C, etc., might mean the following:

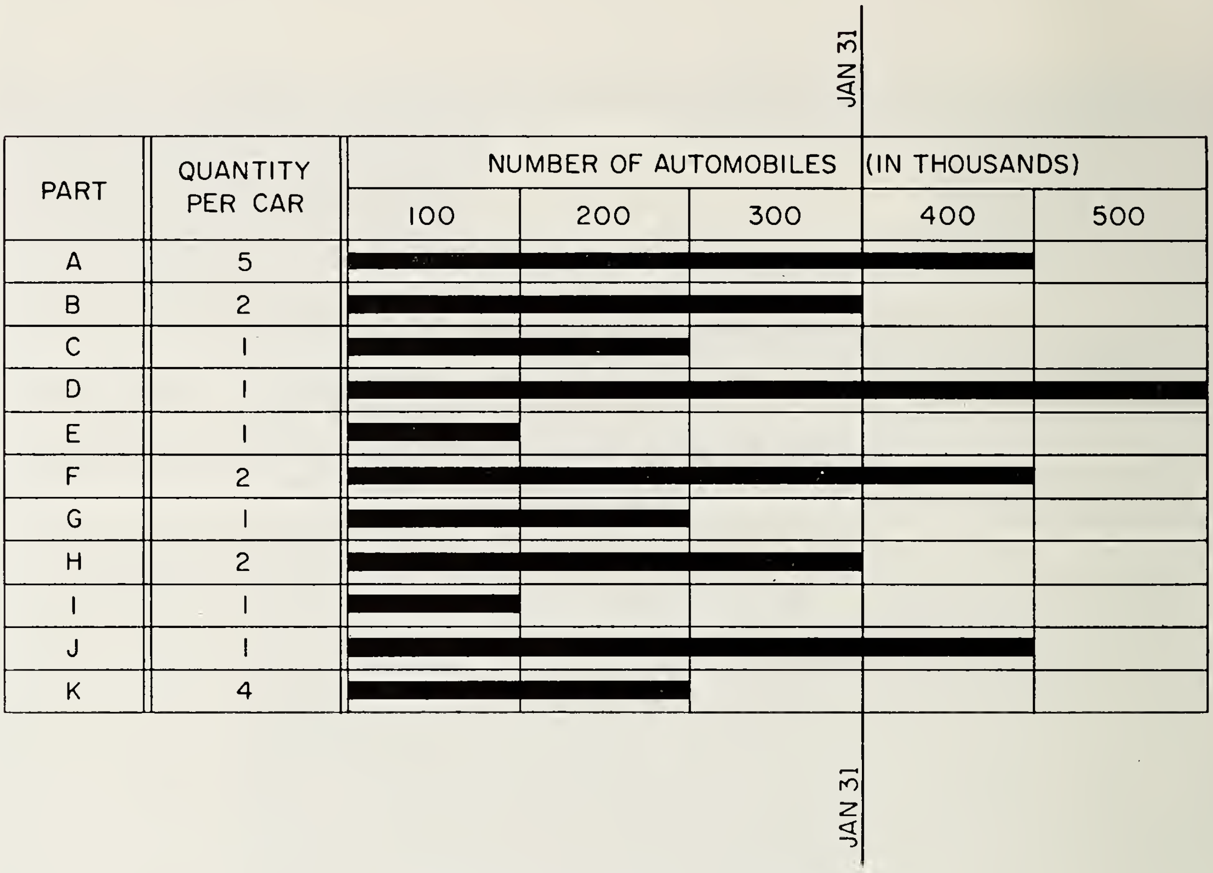

Fig. 9-10. Inventory control chart.

A = wheels (four wheels + one spare)
B = headlights (two headlights)
C = front bumper
D = rear bumper
E = motor
F = windshield wipers (two wipers)
G = rearview mirror
H = tail light bulbs (two bulbs)
I = left fender
J = right fender
K = window operator (four operators)

The bars drawn from left to right represent the total part requirement for a completed automobile (sets of parts) and not the number of pieces. If they were to indicate pieces, they would not be meaningful and a list of figures would be just as useful. In order to obtain the number of sets, the actual quantity must be divided (before the posting on the board takes place) by the number of parts needed to make up that particular automobile. Therefore, if we had 800,000 windshield wipers, F, we would divide the available quantity by 2 and come up with 400 (thousand) sets as indicated by the chart. Let us now see how many wheels we have. The chart indicates 400 (thousand) sets. To determine how many wheels a set represents, we must multiply the quantity indicated by the length of the bar chart with the quantity per car (second column from left). Hence, 400 × 5 = 2000 (thousand) wheels.

If the company's sales forecast indicates that during the month of January the company expects to sell 300 (thousand) cars, the planner draws a vertical line at the quantity column and calls it the January line (January 31). Thus, time can be indicated only indirectly by the expected production (sales) volume.

Let us now see the meaning of the chart in Fig. 9-10. How many cars can we produce with available parts? Since we have in stock only 100 (thousand) motors, the maximum number of cars is bound to be 100 (thousand). Certainly, we have many more wheels and other parts, but the item of least quantity will call the tune. If the company wants to maintain production volume, it is essential to procure quickly the quantity of items C, E, G, I, and K which we are shy. Thus, the chart furnishes us with two basic facts: 1) how much we can produce with presently available component parts and 2) how much must be *a*) purchased or *b*) produced in the shops to meet the sales forecast. For the time being such information as "economical purchase quantity" or "economical production lot" customarily connected with the use of this chart has been omitted. More will be said about economic quantity problems in Chapter 12. At the present time interest is focused on the ability of a chart to give prompt answers to questions concerned with planning the flow of production.

What advantages can charts show over records? Evidently, charts convey information that is vital to production much quicker than dull figures can. Nevertheless, charts are no more than meaningful representations of records. They are, of course, more economical in the sense that they are updated by relatively low-paid clerks on a daily and hourly basis but are used extensively by high-priced planners. The latter can make quick decisions, however complex the production picture. Without charts, the planner would have to spend a great deal more time on the planning process.

The inventory control chart, particularly in repetitive production, is important. Since production scheduling is based on the shortage of parts, the shortage can be revealed by a chart, from which it is immediately known what should be produced next. The assembly plant, for instance, might produce the goods continuously, but the parts are made in economic lots. When the supply of parts is reduced, the shops replenish low inventories.

Earlier in this chapter, mention was made that a customer might, when placing an order, state an exact delivery date as a condition. The task of the scheduler is then to fit the order into the existing plant work load. Mention should also be made that production orders may come from one's own assembly departments and not only from customers. When the chart indicates a shortage of a given part, regardless of whether it is made by an outside contractor or a plant department, it also indicates the quantity of the part which must be ordered. Thus, the chart in Fig. 9-10 indicates that replenishment of C, E, G, I, and K is necessary. Whether the shop order will call for 100 (thousand) or 1000 (thousand) pieces of item C depends largely on other important considerations. While only 100 (thousand) units are actually needed, the shop order might be considerably higher because economic production lot quantity will usually be considered. Barring other factors, the economic production lot quantity tends to be the minimum production quantity even though the actual shortage of the part might be considerably less.

THE IN-PROCESS INVENTORY CONTROL CHART

The in-process inventory control chart is in reality a production control chart and has little to do with inventory control per se. As the various operations on a given material are performed, the volume produced is reported and is entered on the chart. Since production is very likely repetitive, the machinery is used for different purposes on a recurrent basis. The main thing, however, is that enough is always made in the finishing operation to keep the assembly department supplied with usable parts. No money will be invested in operations that can wait. Thus, the product in process is stored in a semifinished form. Evidently, the control chart shows how much inventory is tied up in production, how far processing has advanced, and how many days are needed to complete a given quantity. For machine loading purposes the information thus supplied is invaluable. Such a chart would be used by a fabricating-assembly plant in which the manufacturing departments must supply the assembly departments with parts. Production is always in lots.

Assume that a product, a TV set, consists of several component parts, each going through numerous operations before being considered complete. An in-process inventory control chart, Fig. 9-11, can then depict the availability of the product. Part A might be a plate to be processed through operations 1 to 3, drill press, press brake, and grinder. The chart indicates that the total available units of part A is only 7000 pieces (700 × 10). Although more than 8000 pieces have already gone through the drill press (operation 1), so far as the assembly department is concerned, only 7000 pieces are available for use. Thus, with part A, the 700th TV set can be manufactured, but not the 701st. The in-process chart indicates more than that, however.

The chart also reveals that an additional 1000 pieces of part A are already in the process of production and approximately 500 pieces have already passed through operation 2. Thus, by looking at the load chart for the press brake, it can be determined when operation 2 on the remaining 500 pieces of part A can be completed. For future planning purposes this information is of extraordinary importance. The same thing can be done with operation 3 on the grinder. Thus, the planner can determine at a glance just where production of a part is in terms of output units and time (which are superimposed on a quantitative data).

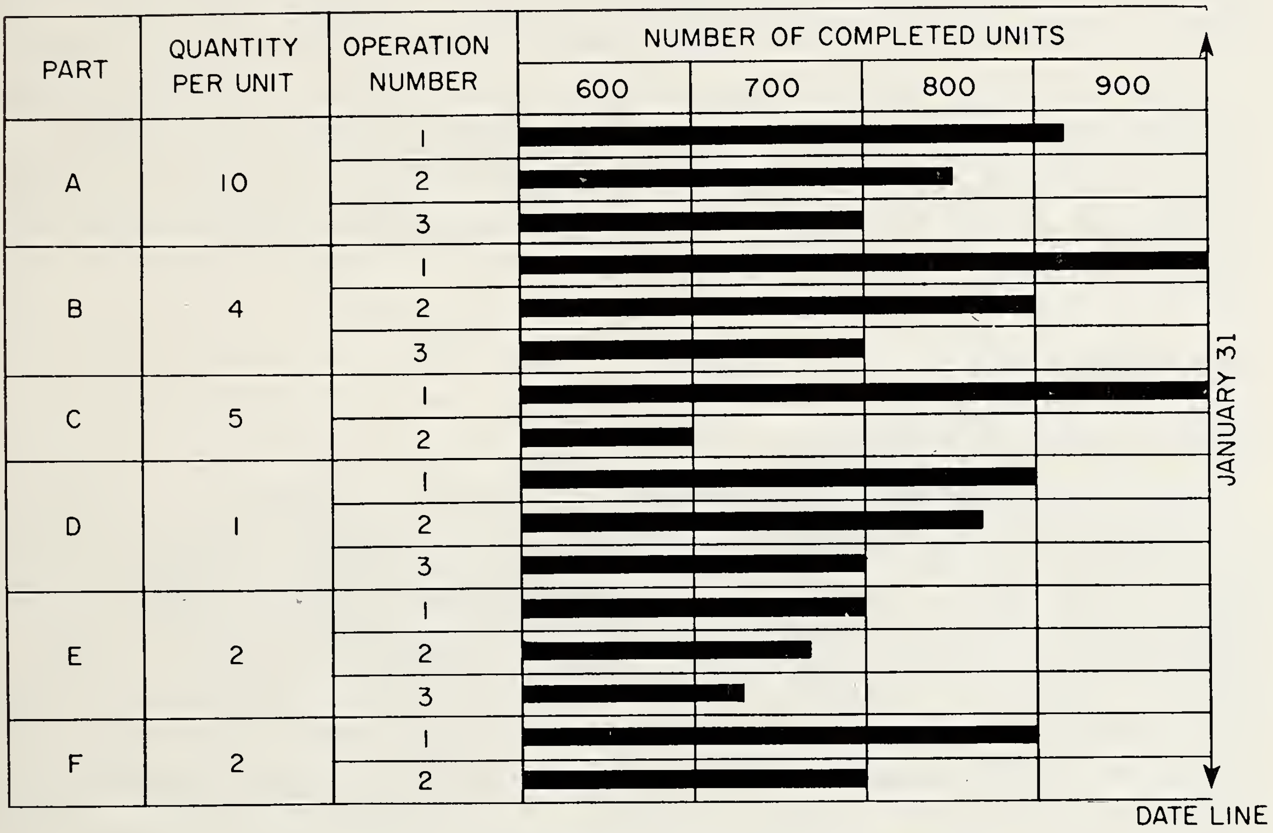

FIG. 9-11. In-process inventory control chart.

The last operation is usually a duplication of the previously explained inventory control chart (that is, the item is at this point a finished item). Production in the machine shop must always keep ahead of assembly; obviously, the production line can not move unless parts are available. Shortage of parts is readily apparent from the chart, and the scheduler knows what part should be assigned to the machinery available in the shop. Usually the operation to be given preference is the one required to complete an urgently needed part. If the target for the month is 900 TV sets, the scheduler can plan the use of particular equipment accordingly. Under the assumption that operation 1 requires a drill press, 2 a press brake, and 3 a grinder, it is possible to figure out, as stated before, how much equipment time is needed to complete all parts in the process of production. The same procedure can be used to determine the time requirements on various equipment to complete the parts B, C, D, E, and F. Obviously, all parts must be placed at the disposal of the production line; otherwise, production must come to a standstill or the foreman must work around the work station where there is a shortage of parts. Often this is not possible, however.

As the student will notice, the chart does not indicate dates, but indicates only production quantities and the items needed. Time, however, can be easily superimposed on the in-process inventory (as well as the finished inventory) control charts. The sales forecast usually indicates the intended sales and the corresponding production figures. Once the production volume for a given date is known, the quantity to be shipped at a given date also represents the deadline for the production of that many component parts. If the in-process inventory chart indicates that, at the end of January, 900 TV sets should be completed, the vertical line indicating the 900th unit of TV sets represents not only a quantity but also a date for that amount of parts. Thus, it becomes essential to check the other charts which might be involved to see whether the machine or the department in question has sufficient time available to complete the parts by the deadline given.

SUMMARY

THE FUNCTION OF CHARTS

Charts facilitate the thinking process by enabling the planner to visualize the production situation. Plans are based on facts logically arranged by the planner. The difficulty with the logical arrangement increases with an increase in the volume of data with which the planner must work. Furthermore, the task of the planner is complicated by the interrelation of the factors. Growing volume of data, cross-relationship, direct and inverse correlation between relevant factors, and many other complicating elements make planning—and decision making—a delicate and difficult task. To simplify a difficult and at times promptly needed plan, charts were developed to graphically present the multiple factors in relationship to one another.

By using charts, the production planner (in large companies a whole group of men constitute the production planning department) can see the relationships between factors. Also, from the relationships and the visual reflection of certain happenings, he can find answers to questions which would otherwise be difficult to answer. That is, answers to questions necessary to formulate production plans are readily available to those who are capable of reading charts. Although the charts are relatively easy to read, a certain amount of experience is necessary to find the information that is wanted.

However well designed it is, the chart does not provide the planner with the needed information unless it is kept up to date. This, of course, does not imply that the planner himself is the one who must keep the chart up to date. As a matter of fact, one of the distinct advantages of these charts is that the planner can find the answers quickly without involving himself in mathematical calculations which are time consuming as well as clerical in nature. Thus, the routine posting of information on the chart is assigned to low-paid clerical personnel. Nevertheless, the planner and decision maker can work with these charts just as well as if he were the one keeping them up to date.

VALUE OF CHART

The basic idea behind a production control chart is that "a picture is worth a thousand words." Anyone who has ever asked information on how to get to a certain location knows that most verbally given instructions are difficult to understand. The same information in map form is more concise and is easier and quicker to understand. The charts serve exactly the same purpose as a map.

Production is based on plans. Plans, in turn, are nothing but the allocation of the factors of production in advance of performance. However, the production planner's "planning efforts" are restricted to allocating the material means of production to divergent uses—as opposed to allocating the human resources of production. In the case of intermittent production, the production planner allocates plant capacity, that is, equipment time, and checks availability of raw materials to make sure that production is accomplished in accordance with customer delivery requirements. In the case of repetitive or continuous production he allocates in light of overall plant capacity the departmental work loads and/or production time in accordance with the sales forecast figures.

The allocation of available physical facilities, the time necessary for production, and material requirements at any given time are so diversely connected with one another that a picture is necessary to show all the relationships. Without a clear picture of the interactions of the factors affecting the decision, production efficiency cannot very well be achieved. That is why the business world developed charts and graphs capable of depicting the production situation. The chart gives the production planner, and anybody else connected with industrial operations, graphic information about the status of operations, departmental work loads, and availability of necessary raw materials. Those concerned with production can then easily see what is happening in the shop.

CONVENTIONAL CHARTING TECHNIQUES

The Gantt chart was used in the past to illustrate the production situation. The Gantt chart is a bar chart capable of illustrating interrelated factors —and at times even more. Usually we have a vertical charting technique which must be brought into relationship with factors listed on the chart horizontally. The interaction of the vertical and horizontal lines give information needed in the production planning process. The Gantt chart can be used for the following purposes:

1. Master scheduling (repetitive and continuous production)

2. Departmental work load scheduling (intermittent and, especially, repetitive production)
3. Machine loading (that is, assigning work to equipment in the intermittent type of production)
4. Follow-up of progress toward the schedule (intermittent production)
5. Control over availability of raw materials (repetitive and continuous production): a) purchased items, b) in-process inventories, c) finished items.

The conventional technique of charting requires the use of paper divided into squares. Each square can represent either quantity or time. By drawing appropriate bars of squares along the comparative factors listed chronologically on the horizontal lines, progress toward a production schedule can be followed up, availability of equipment can be seen, and availability of raw materials both purchased and in-process can be readily ascertained. Depending on the use which is made of it, the Gantt chart assumes the following names: 1) load chart (master scheduling, departmental work load scheduling and machine loading), 2) progress chart, 3) inventory control chart, and 4) in-process inventory control chart.

MODERN TECHNIQUES

Although the conventional techniques are widely used for planning purposes, many enterprises are switching over to modern versions of the Gantt chart sold by such companies as Graphic Systems, Remington Rand, and Wassell Organization, Inc. Furthermore, since some of the charts give information needed for further planning purposes, the computer is used in place of the visual control charts. The computer can duplicate the accomplishments of visual charts. However, the computer is applicable primarily in large corporations where the production volume is large enough to warrant the expense of such an electronic device.

Boardmaster Visual Control. The Boardmaster Visual Control is especially suitable to master scheduling and departmental work load scheduling and is useful to a limited extent for machine loading purposes. These purposes were listed merely as a matter of preference on the part of this author. The chart can be used in the same manner as the charts illustrated in the section explaining Gantt charting. However, they can be made without drafting skill and the use of pencil or paper. The chart gives the planner a graphic picture of plant operations, spotlighted in color. It is simple to operate and plan with and it is flexible—easily adapted to the needs of the given production organization. Typewritten information on interchangeable cards which snap into grooves gives the planner a compact picture of plant operations.

Sched-U-Graph. The most adaptable use which can be made of the Sched-U-Graph is in the field of machine loading. It eliminates frequent redrawing of charts. Since production situations change, orders are canceled, and rush jobs take precedence over other jobs, the load chart changes very fast. Since cards are cut to size and can be placed into the chart, it is easy to accommodate changes necessitated by a breakdown or other unexpected occurrence. Otherwise, the chart illustrates exactly what the Gantt load chart illustrates. The only difference is that the information does not have to be drawn, since it is only inserted in appropriate pockets. The author's preference as far as machine loading is concerned is the Sched-U-Graph.

Produc-Trol board. Progress control can easily be had by the use of the Produc-Trol board. Since the follow-up line uses a retractable band, it is convenient to follow the progress toward the schedule which is depicted on top of the follow-up line. The schedule indicates finishing dates operation by operation. Reports of operation performance come from the production shop. The follow-up retractable band is advanced and positioned below the accomplished performance. Another band located vertically on the board shows the date day by day. When a follow-up line is to the left of the today line, it is likely that the operation is behind schedule. Investigation, correction, and rearrangement might be the result. As far as progress control is concerned, in the opinion of this author, no better means than the Produc-Trol board is available on the market.

The Computer. Computers presently available are capable of retaining information, receiving additional information, and performing the addition or subtraction functions. In production planning work we are primarily concerned with logical arrangement of information and comparative evaluation of available (or programmed information) data relative to new data, and the computer can make the necessary arrangements with great speed. Therefore, the planner can get information quickly without having to check charts for the necessary basis of decision making. Since the computer makes computations upon receiving new data, it can do practically the same work as the visual charts. In some respects the computer can do a better job than visual charts. However, the disadvantage as far as computer-furnished information is concerned is that the planner does not see the production situation in front of him at the time the information is used and the decision is made. However, since the information furnished by the computer is reliable, most planners do not care whether they see how the particular decision affects all the other factors and the total plant situation.

QUESTIONS

9-1. What is the advantage of using charts in the planning process?

9-2. What can charts do for management that dull figures, data, and other relevant information in written form cannot do?

9-3. What are the general principles underlying the Gantt chart?

9-4. Do all sizes of production enterprises need to make use of some sort of visual charts to depict their operations? Explain.

9-5. How would you go about setting up a production control charting system?

9-6. What knowledge is required in order to be able to read and understand a chart used in production planning and control work?

9-7. For what purposes can Gantt charts be used?

9-8. What are the factors which place limitations on the use of departmental work load charts?

9-9. How would you master-plan the production program of a repetitive manufacturer engaged in fabricating-assembly production?

9-10. How do the machine and the departmental work load charts operate?

9-11. How would you, by means of the progress chart, keep track of various orders?

9-12. How would you set up and make use of an inventory control chart?

9-13. What are the advantages of charts sold commercially by Graphic Systems, Remington Rand, and Wassell Organization, Inc.?

9-14. Which companies should use computers for production control work in lieu of charts and charting systems?

9-15. What are the advantages and disadvantages of the computer in comparison with the charting system?

9-16. Which charts might be used by a continuous producer?

9-17. If you were a planner in an intermittent job shop, which charts discussed in this chapter would you use to gain information about facts and relationships to facilitate your planning effort?

9-18. What charts are applicable in repetitive production and for what purposes?

9-19. What is meant by charting a production program?

9-20. Who in a production control office would be responsible for updating and maintaining the various charts used in the production control work?

PROJECTS

9-1. The president of XYZ company wants to know immediately the effect of three orders on company operations. The XYZ company is considered to be a repetitive manufacturer because the orders which the company accepts are long-run orders in sizable quantities and production is in economic lots. The three orders in question would extend production over a period of 10 months and 100 pieces must be delivered each month from each type of unit (that is, each order).

The president wants to see a prepared 1) master schedule, 2) progress chart for parts, and 3) machine load chart. The facts to prepare these charts are as follows:

Order 112 consists of four parts, namely, A, B, C, D
Order 113 consists of four parts, namely, AA, BB, CC, DD
Order 114 consists of two parts, namely, AAA, BBB

Each of the above mentioned parts goes through the operations in the accompanying table. To simplify matters, the assumption should be made that all operations denoted by 1 represent milling operations; by 2, drilling operations; by 3, tapping operations (tapping is done on a drill press just as drilling is); and by 4, grinding operations. The sequence of operations is not interchangeable. According to the sequence, part BBB, for instance, must first go through a grinding machine, then through a tapping (drill press) machine, then through a drill press, and finally through a milling machine.

Part	*Number and Operation Sequence*
A	1→2→3→4
B	4→3→2→1
C	2→2→1→1
D	2→2→1→1
AA	1→2→3→4
BB	4→3→2→1
CC	2→2→1→1
DD	2→2→1→1
AAA	1→2→3→4
BBB	4→3→2→1

Although in actual practice each operation would take a different amount of time (that is, standard time), in view of the fact that the material might be different or the hole might be deeper or larger, the example is simplified by assuming uniform machine capacities (see the machine load chart). After the parts are completed, they must go through inspection, painting, and the assembly process (the latter is not detailed). Thus,

parts fabrication ⟶ inspection ⟶ painting ⟶ assembly

Final assembly, 80 units per day (capacity). The 80 units per day capacity is derived from the fact that each unit requires a total of 1 man-hour and there is a crew of 10 assembly workers. Hence, the output is 80 man-hours and therefore 80 units per day.

Painting, 100 parts per day (capacity).

Inspection, 100 parts per day (capacity).

Fabricating capacity is indicated on the load chart shown in the accompanying illustration. Care must be taken in determining the availability of the machines. The various machines needed are busy with other work in January when the first shipment from each three orders will have to be made. Thereafter the plant has no work. Deliveries should start, if possible, in January. The task of the student is to comply with the desire of the president: prepare a production program for the 10 months and set up a production schedule on the first line of the progress chart. (The second line to be filled out during production, that is, as production is in progress.) In case of difficulties, indicate the need for overtime work and the way you would handle the situation in order to gain the best cost structure (utilize the more efficient machine more extensively).

CAPACITY PER DAY	MACHINE	6 WEEKS									
		1	2	3	4	5	6	7	8	9	10
			JANUARY				FEBRUARY			MARCH	
100	M-1		▬								
50	M-2										
100	D-1				▬						
50	D-2			▬							
50	D-3		▬								
100	G-1			▬							
100	G-2										
50	G-3			▬							
50	G-4										

9-2. To produce one unit of toothpaste the following ingredients are necessary:

Part (ingredient)	Percentage
A, liquid	10
B, powder	23
C, powder	33
D, liquid	24
E, powder	10

The stock records indicate that we have 200 gallons of ingredients A and D, 150 pounds of B and C, and 100 pounds of E.

Construct an inventory control chart which clearly indicates the number

of tubes of toothpaste which can be prepared from the available raw materials. One drum (2 gallons) of toothpaste equals 100 tubes.
The student should be reminded that he must find a *common denominator* before he is capable of charting the status of raw materials.

9-3. Set up a system of production planning and control charts in an industrial enterprise which is engaged in repetitive production of ten different items: radios, television sets, vacuum sweepers, radar equipment, and field telephones. The two latter are a part of a military long-term contract; the other three items are company standard items sold on the open market. Production quantity is developed (determined) on the basis of sales forecasting figures. Each of the above items is made in two different styles.

9-4. An aircraft manufacturer receives an order from TWA for 50 jet-propelled passenger planes. Although the aircraft manufacturer is very busy with other orders, he hopes to be able to accept the order for an early delivery. On the assumption that most of the processing considerations were already determined at the time the company prepared a bid, the problem centers now around the scheduling of the order. How would a company go about solving the scheduling problem and what charts must be constructed (or utilized) to see the production plan at a glance and to keep track of the progression of the order?

9-5. Assume that a coal mine keeps charts about coal already mined. How could the mine determine at a glance how much coal it has at hand in toto assuming different combinations of Btu (British thermal units).

The student should know that coal mines receive orders for coal with different heating power, or Btu (British thermal units) quality. Apparently, different industrial enterprises need coal with different Btu content. Depending on the geological formation, the coal gained from different seams can be of different Btu content. Coal with high and low heating power (high and low Btu content) must be kept apart, and when orders are received, the company must ship the right mix of coal with the required Btu content. In South America or Continental Europe, however, the calory instead of Btu is used as a unit of measure. (A calory is that heating or energy potential capable of raising the temperature of a cubic centimeter of water one degree centigrade; a British thermal unit is the amount of heat necessary to raise the temperature of one pound of water one degree Fahrenheit.) Thus, the question is this: If the mine has x quantity of a Btu coal, y quantity of b Btu coal, and z quantity of c Btu coal mined, etc., how many customers for x quantity of d Btu coal could be satisfied from the available stock?

chapter 10

Sales Forecasting for Continuous Production

THE SALES FORECAST

Unlike the job shop, the continuous manufacturer produces for stock. But to know how much to produce and at what rate to place the output units at the disposal of the dealers, a sales forecast must be available. Being concerned with sales rather than with production, forecasting is not a production control function (even though it might be performed by the production control department), but it is vital information on which the rate of material flow to and from the production line must be based.

Just as job shops would find it difficult to plan optimum utilization of plant facilities unless time standards and charts depicting relevant production information were available, so it would be difficult in mass production to schedule without having precise advance information about the possible demand. The collection and evaluation of data used to predict future sales, that is, production requirements, is sales forecasting.

The ultimate success of a mass producer depends on his ability to forecast his future sales so accurately that neither more nor less is produced than is actually needed. Furthermore, it is also important to set the rate of production in accordance with the possible rate of sales. To make a sale, the goods must be on the shelf of the supermarket, in the store, or in possession of the dealer at the precise moment any customer wants to buy it. If the goods are not available, and barring a monopolistic market setup, the sale is usually not only postponed but irretrievably lost. Most consumers in need of the goods in question have no compunction about choosing a competing product as long as it meets their requirements as to quality, price, and functional utility. Since a loss of a sale is permanent, no continuous manufacturer can afford to be caught short of inventory, and, by the same token, no producer can afford to be stuck with a big inventory either. Both can be very expensive! Accordingly, the sales forecast must accurately predict when the first 100, 200, 300, 500, 1000, 2000 units must be ready and what the aggregate output should be during the next forecasting period, or with a reasonable degree of accuracy, segments thereof.

Considering the severe financial consequences of either over- or underproduction, sales forecasting errors can cut into profits and raise costs of making the goods, even if the expenses which are associated with sluggish sales (storage costs, inventory carrying charges, risk of obsolescence, etc.) are disregarded for a moment. Yet, despite its extraordinary importance, it is truly a formidable task to predict the volume of sales in this competitive world, where substitute products mushroom, where consumer tastes change overnight, and where economic conditions often take sudden turns responding to legislative actions or fiscal policies. Nevertheless, no large-scale manufacturer can afford to be without a sales forecast. Evidently, if decisions had to be made at the last minute, they would delay getting off the ground, because 1) the raw materials necessary for production could not be obtained on short notice, 2) the plant could not be tooled up fast enough, and 3) what is probably more important, costs could not be controlled to the extent required by competition. Apparently, in order to get things organized and moving, time is needed—often several months. This is in addition to the time the production cycle itself takes—which also might extend over several months until the pipeline is filled and products start coming off at the end of the production line. Thus, unless the exact amount which can be sold at any given future date is known (that is, believed to be known), production decisions cannot be made in accordance with consumer demand and cost considerations.

An overoptimistic appraisal of the industry's sales, including one's own share of the market, might result in being caught with enormous quantities of inventory. The carrying charges and the erosion of profits which excessive inventories bring about are often more significant than the actual storage costs (rent, heat, maintenance, insurance). The working capital tied up in idle inventories is usually borrowed, and interest must be paid on the loan. When inventories do not move, the interest payments can be quite substantial. The erosion of profits might, however, be attributed to distress selling associated with overproduction. Discount prices become necessary primarily because mass products tend to have elastic demand, meaning that in order to accelerate sales, the price must be reduced to make it attractive to a broader consumer group. Although the reduction in price often takes the disguised form of trade-in allowances, the fact that profits are being squeezed out cannot be denied. Evidently, this kind of expense could have been fully avoided had the producer been foresighted enough to produce neither more nor less than the actual sales conditions warrant. Accordingly, overproduction manifests itself in rising costs and falling profit margins.

Underproduction also has undesirable financial consequences that are similar to those mentioned above. Each unit which could have been sold—but was not—is an implicit loss, a loss in a sense that the sale of each unit contains a small margin of profit. The aggregate sum of tiny profit particles—provided the underproduction represents substantial amounts of goods—might add up to a serious sum of money which was irretrievably lost.

Not only erosion of profits but also rising costs are interlaced with underproduction. If larger volumes cut unit costs by a better distribution of fixed costs, then the production of a smaller volume will have the reverse effect. Hence, a volume lower than that warranted by sales means greater unit costs due to a failure to take advantage of the scale of production. How significant the amortization of capital costs (undistributed fixed costs) can be is illustrated by the fact that the investment in plant facilities can range from $8000 to $15,000 per employee in metalworking and $30,000 to $55,000 or even more in process industries. Each man-hour of labor which remains unused because the company misjudged the market can be a severe blow to the company's cost structure. Depreciation allowances are inadequate as they are, and it is commonly contended that they are lower than obsolescence of the equipment. At any rate, if a plant fails to take advantage of the amortization, it is a clear indication of inadequate forecasting.

The need for accurate forecasting is also evidenced by the fact that, in the final analysis, volume will determine the extent of mechanization and the depth of tooling. The tools, not to speak of the physical facilities themselves, cost a small fortune as far as most mass producers are concerned. Obviously, unless volume warrants careful tooling, the acquisition of costly special gages, jigs, and fixtures might be folly. Large volumes, however, make it worthwhile to build expensive and highly productive tools because they repay their acquisition costs long before the production run or the model year is over.

No large-scale producer can therefore afford to be without a sales forecast; yet on the surface it appears that most manufacturers would not forecast. Nothing can be further from the truth. Some companies do not call it forecasting, but their future expectations are based on sound judgment, careful study of records of the past, and a good mixture of foresightedness and preplanning.

Whether sales forecasting is assigned to a staff of specially trained forecasters—statisticians, economists, and market analysts—or to executives whose major interests lie elsewhere is relatively unimportant. The sales forecaster must, in any case, be free of bias and must base his opinion on reliable facts instead of on hunches. Although judgment in forecasting is customarily condemned, it is still an important ingredient of foresight. We are not talking about mere guesses, but about informal studies and manipulations of facts, including economic, political, and fiscal happenings, and translating them—mentally anyway—into production plans.

Although the results of forecasting can be used for a multiplicity of purposes (setting realistic sales quotas, evaluating sales territories, budgeting sales expenses, and making financial decisions) in this book its purpose is relegated to discovering, by a scientific procedure, the probable sales volume in order to determine the best production schedule. To allocate production capacity so that the predicted sales volume is being made available when needed (that is, manufactured by the production departments), without neglecting to keep the costs at the minimum, would be impossible without a breakdown of the product mix and yearly sales into quarter-yearly output volumes and monthly output quotas. Only after a sales forecast is available can a production program be mapped out, the flow of materials to the plant and within the plant be regulated, economic production lots established, lead times brought in line with production requirements, and all sorts of interrelated production decisions be made to attain efficient production. Hence, in mass production, of both the repetitive and the continuous variety, all production decisions are predicated upon the sales forecast.

BASIS OF FORECASTING

Since the object of the forecasting procedure is the determination of the sales volume and the monthly sales quota, it is evident that a "crystal ball" which can point up future sales possibilities must be found. Of course, such a crystal ball does not exist, but observations, records, and statistically valid relationships do exist, and they make forecasting possible. Thus, if history repeats itself, we can use history to forecast the future. In sales forecasting this is exactly what we do; we predict sales on the basis of the past. Records, both in the narrow and in the broad sense, can show how consumers behaved in the past. Assuming that the past bears some resemblance to the future, the planner can master the future. Of course, in a world of planned (and unplanned) obsolescence, one may not be wholly preoccupied with the past. Just the same, there is a strong probability for the recurrence of past happenings, merely because human nature and human buying habits do not change overnight.

What has so far been said may seem to be doubletalk; what probably should have been said is that we rely on statistics but we do not blindly follow the suggestions made by figures. Figures can lie as well as tell the truth, depending on the skill of the forecaster. The accumulated data must, of course, be both valid and reliable; only then can they be used by the forecaster to predict certain future probabilities. In other words, sales forecasting is largely a reliance on the mathematical probability theory on the one hand and on sound judgment on the other. It follows then that forecasting is inductive in the sense that the conclusions are derived from observations of the past (past sales and economic relationships).

The function of forecasting is not to fabricate figures, but to appraise the future as accurately as is humanly possible. To attempt this, it is obvious that a sufficient amount of data must be available to warrant the various conclusions. It is a well-known fact that what single consumers will do cannot be predicted, but what people will do en masse can be, simply because members of any given society unconsciously develop certain buying patterns. Although we do act erratically, we tend to fall into certain patterns. This pattern must be "detected" and enlisted to serve sales forecasting. The statistical analysis, based on valid and reliable data, will strengthen predictive power —it will not, however, guarantee it. Whether the approach to a prediction takes one form or another is, of course, important to the extent that simple averages, measures of dispersion, trends, seasonal or cyclical variations, coefficients of correlation, index numbers, and so on are able to reduce the guesswork ordinarily associated with certain judgments. Furthermore, the already available statistical measurement techniques tend to permit, by observation of quantitative data (past sales experiences in light of other statistical parameters), more logical conclusions than otherwise could be made. To fall into the pitfalls of fallacies of logic is easy. Probably for this reason, it is advisable to turn over the task of collecting, analyzing, interpreting, and presenting quantitative data to expert statisticians.

METHODS OF FORECASTING

To find the answer to how many (or how much) and when, the forecaster might have recourse to the micro and macro statistical forecasting techniques (concluding on the basis of the parts to the whole or vice versa). Each technique has its merits and demerits, but either one of these two approaches can lead to good results in the hands of experts. It is claimed, however, that "the most progress has been made in building up sales forecasts from small geographical segments, i.e., the local markets."[1] Those opposing this view claim, in turn, that[2]

> it is downright impossible to make business decisions that way. Try to imagine a business man who would operate in the same way whether he expected a recession or a major business upsurge. We are all together in the same economy. What happens to many of us gets passed on to others like an infectious disease. No matter how much one might like to do so, he cannot go it alone. In economic matters, businessmen are truly living in one world. Consequently, the economic forecast is the first step in estimating a firm's sales. The second step generally is a forecast of the industry's total sales. With the latter as a basis, a firm can forecast its own sales—by projection of its market share or by some other means. Because so many of every company's decisions about production, purchases, plant expansion, etc. revolve about its sales forecast, a general

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[1] Peter G. Peterson, "The Use of Media in Making Sales Forecasts," Special Report 27, American Management Association, 1957.

[2] A. R. Oxenfeldt, "The Preparation and Use of the Economic Forecast," Special Report 27, American Management Association, 1957.

> economic forecast may be said to render its greatest single value when used as a basis for a sales forecast.

As stated previously, it is basically immaterial how the forecast is made as long as it reflects the future business situation with a great deal of accuracy. The failure to arrive at reliable sales figures can be the cause and the effect of present and future business problems.

By reading the statement of the exponent of the micro statistical approach, one would assume that the national economy as the paramount influencing factor is disregarded. Nothing can be further from the truth. Salesmen, district sales managers, and men located in the territory do not make their judgments in a vacuum. They keep their eyes on both the local situation and the national happenings. Of course, it is true that most salesmen are not equipped to judge the effects of lower or higher discount rates, taxes, minimum wage legislation, etc. on overall industrial sales. Thus, the advisability of the second approach stems from the fact that a purposeful comparison between economic happenings, seasonal and cyclical fluctuations, industry trends, and other factors might lead to a better appraisal of the future.

Evidently, a good sales forecast is bound to be based on both the micro and macro statistical approaches in the sense that in the final analysis a compromise is reached between the two. At any rate, 1) the general economic conditions, 2) the expectations of the industry in which the company in question operates, 3) the company's share of the total industry sales, and 4) past company sales, based on accumulation of company records, and all other relevant information, must be kept in mind when future sales are predicted.

SOLVING THE FORECASTING PROBLEM

Barring significant changes in the economy, consumer behavior reflects a predetermined pattern. For this reason, sales forecasting is possible. Nevertheless, blind reliance on factual data must be eliminated simply because statistics show merely a trend, a pattern, and a system of consumer behavior in the past; and they are no crystal ball for future consumer behavior. The main advantage of the knowledge and know-how of the statistical tool is that a forecaster trained in unbiased interpretation of data is able to limit the area in which he must use his judgment. Knowledge of statistics facilitates to some extent also the judgment part of the forecasting procedure in that certain statistical rules, serving as indicators, can guide the forecaster in arriving at certain predictions of an intangible nature.

All in all, the forecaster should use statistics whenever the statistical data can serve the best interests of the prediction (and enhance the forecaster's ability to be accurate) and use his seasoned judgment on issues where the past is not necessarily representative of the future. Hence, the seasoned judgment of experts, shrewd and otherwise professional guesses, etc., should not be underestimated. Innovation is always an element in forecasting. Only those who can tear themselves loose from bias and take a fresh look at the future and exercise the same kind of intelligence and inventiveness that competitors practice can preserve their company's profitability.

THE FORECASTING PROCEDURE

The procedure for making a sales forecast involves two separate but related activities. First of all, the existing sales position of the firm for which the forecast is made must be determined. Second, one must know the overall economic situation and predict the coming economic, competitive, and intracompany forces which will shape and form future sales. Basically, the sales forecast function requires availability of past sales records and other appropriate information. An analysis of the latter is based largely on conjectures. Nevertheless, in economic matters the cause and effect relationships lend themselves to factual analysis.

Gathering Required Information

A considerable amount of information is required for sales forecasting. In relation to economic factors, it is necessary to collect a series of economic indices which are relevant to the industry within which the company operates (disposable income, taxation, population growth, national output, bank deposits, employment figures, price levels, etc.). If the forecaster is equipped with a profound knowledge of economics, he can make important conclusions on the basis of economic indices. This is possible merely because the forces motivating and rotating the wheels of business are not wholly capricious and haphazard, but are derivatives of ascertainable causes. Hence, a careful analysis of current happenings in the economy provides strong clues to what might happen in the near or distant future. The only trouble with published economic facts is that they have not been written with specific purposes in mind. In other words, they are not so designed and collected as to serve any particular firm in the economy. Thus, a considerable amount of guesswork and interpretation is required in molding information into a shape and form which actually serves the purposes of the forecaster.

The next step in the forecasting procedure is the collection and interpretation of industry sales figures (dollar value of sales, total quantity sold, breakdown of various items into industrial and comparative classifications, etc.). The data on industrial sales are important because, if the industry as a whole expects good business, the chances are that any given member of that industry will likewise do well. Of course, it is not easy to obtain industry figures, because many enterprises do not report their total sales. Such information, if at all available, can be obtained from stockholders reports published by companies. The latter might have to be "doctored" to some extent, which, of course, might clarify or distort the picture as far as the user of the forecast is concerned. Furthermore, the difficulty that arises is that sales are reported in dollar value rather than in quantitative data. Even if stockholders reports indicate the total number of units sold, the important information as to product mix is seldom spelled out.

In some fields, the various members of the industry belong to an association, such as the American Iron and Steel Institute, which collects and publishes output and sales figures in rough breakdowns. It is evidently advantageous to report to, and, in turn, be informed of, production facts by an association.

The last, but by no means the least important step is the collection and interpretation of company sales figures (dollar value of sales, classification of sales into products to reveal product mix, style differences, qualitative differences, etc.). The records can, among other things, be classified into factual records and presumptive data depending on the reliability of the information. As long as the company kept records, say, during the past twenty years, the records might be quite indicative of the future unless substitute products gained more acceptance. In the latter case, not only company records but also records reflecting consumer preferences in favor of substitute products must be collected. In other words, the records must be so organized that they reflect true trends affecting the company's future sales.

When, in addition to these company sales figures, the sales territorial reports of expected sales quantities are tallied, it is possible to set aggregate sales based on the opinions of salesmen, sales executives, and territorial experts in light of past sales experiences.

USE OF AVAILABLE STATISTICS

On the assumption that the data (economic indices, industry sales figures, company sales records, breakdown of sales into product styles and models) necessary for a forecast are available, the task of analysis and interpretation of statistics can begin. As stated previously, the approach is relatively unimportant, but the conclusions reached must reflect reality. This means, of course, that the researcher must follow accepted statistical inference techniques. Errors in logic might distort the forecast and, of course, the value of the sales forecast itself. Without trying to advocate any specific method, the following suggestion will in most cases have satisfactory results:

1. Only such economic indices should be selected as are definitely pertinent to the industry and the company in question. Accordingly, a decline in the national income tends to affect various industries (and companies within the industry) differently. In contrast, a deflation might conceivably affect producers of luxury items more severely than producers of necessities, and certain firms in the luxury group might be more sensitive to declining national income than certain others. If the product's life can be prolonged through repairs and added maintenance, repair shops, for instance, can expect better rather than poorer business during a period of declining national income.

Whereas in some companies a single economic indicator can be a sufficient clue to future business, in others several interrelated indices are usually needed if conclusions are to be valid. Cement producers might have to conclude on the basis of falling or rising disposable income (an indicator of building boom or bust) whether to raise output or to retrench operations. While it might be true that with falling disposable income a building boom will come to an end, there might at the same time be an increase in highway construction, so that the situation might be good so far as the cement maker is concerned. Therefore, the forecaster must select all meaningful economic indices capable of influencing sales one way or the other. Certain economic factors might adversely affect a given company's sales, yet other happenings —legislative or fiscal—might counterbalance them with the net result of little, if any, change in the aggregate demand for the industry's and the company's products.

Firms engaged in repetitive production, for instance, are somewhat less sensitive to economic happenings because of their ability to convert their production facilities to multiple uses. Convertibility of equipment operates within narrow ranges, but it is nevertheless true that the repetitive producer can better adjust to economic changes as well as to shifts in demand than the purely continuous producer can. In this case, sales forecasting will serve the planner as a basis for determining the best utilization of plant facilities in light of demand for different combinations of product mix.

It should be emphasized, however, that a shifting environment might precipitate fewer problems than one would assume. For example, an automobile producer selling passenger cars in one period can convert to the production of military jeeps and trucks without much problem. A missile producer can have excellent business despite a generally depressed economy. Thus, if there is a decline in one type of consumer product, a loss of business in that section can be counterbalanced by a gain in another sector. Of course, switching from the production of cars to the manufacture of landing gears might be more problematical than converting from luxury liners to battleships or destroyers.

Even though the correlation between several economic indices is at times remote, it can be quite significant in the sales forecasting procedure. Thus, it requires a keen insight into economic relationships to find relevant cause and effect relationships. In the attempt to select relevant economic indices, special attention must be devoted to these remote relationships. Probably for this reason, many companies do not make their own economic forecast but instead hire the services of consultants or subscribe to the various professional forecasting services (Kiplinger, Babson, Standard and Poor, L.D. Edie, National Industrial Conference Board, Monthly Letter of the First National City Bank, Barron's, etc.).

2. The economy affects not only the individual firm's future business but

the business of the industry as a whole. If the industry expects to do well, the chances are that the company can also do well. This, of course, is not a necessary corollary. While it is not easy to get industry figures, once they are collected or somehow acquired they must be organized by dollar value of sales and breakdown into product groups. For many industries, a rather broad classification of industry sales figures is collected by the United States Department of Commerce and other governmental agencies. In some other industries, the manufacturers' association can furnish sales data.

Sales must often be broken down into minute details to be meaningful; thus, the production planning and control group must decide exactly how many units are in each product group. Because some parts are common to all units whereas some others are unique, it is important to determine how many of the "basics" (items common to all output units) and how many of the "specials" were turned out in the industry. The time factor is also of importance, and for this reason the industry forecast must be broken down into half years and then into quarters and months. Thus, the forecast also represents an indication where the consumer demand rises or falls during the year. An accurate appraisal of seasonality can be of great help as far as the production control department is concerned.

By now it must be apparent that industry sales cannot easily be broken down into product lines or into smaller segments, even if the industry volume is known. Yet, individual industrial enterprises must know not only the overall dollar sales and the rough breakdown of product mix, but also quite specific things about production details. The total ingot, strip, and sheet output of the steel industry might be significant, but most companies would also like to know what types, grades, gages, and widths were produced and sold. Obviously, from reported industry figures only the overall picture can be seen. Thus, a great deal of improvizing and guessing must take place before a company can finally arrive at its own sales forecast. The industry figure can, at best, serve as a guide to one's own data, but it does not state the product mix in precise terms.

3. The sales figures kept by the sales department are of course of great importance. These figures show not only the overall sales figures (as the industry sales do), but also the product mix sold in the past. A careful evaluation of the records of the past might reveal certain recurrent sales percentages from given product lines, models, and styles. Thus, an automobile manufacturer might notice that a certain percentage of the buying public always buys two-door sedans, whereas another group, a fairly constant percentage of the total, always buys four-door sedans. This information, when further evaluated, might give clues to how many different types of doors must be stamped out in the stamping plant and what the relationship between parts and components which make up a door should be.

When evaluating one's own sales data, often only the large-volume items warrant careful analysis. Accordingly, a great deal of time is spent on the large-volume items and a correspondingly smaller amount of time on small-volume items. This is applicable to companies making hundreds of products. Whereas overproduction or underproduction would have the same effect regardless of whether large or small volumes of an item are involved, the loss might be the greatest in overproduction. This is, in a way, something like time study. A more careful analysis is required on long-run than on short-run jobs.

4. The collection and analysis of data should not be restricted to the group itself. It is obvious that the data collected are of little use unless they they are looked upon in the proper light. For that reason, the data should be examined in the following logical pattern: a) economic versus industry data, b) industry versus industry data, c) industry versus company data, and d) economic data versus company sales records. The industry versus industry data might be very important to the producers of a product that is in competition with other product groups for the same market, as producers of steel compete with producers of cement, glass, fiberglass, aluminum, and plastics. Thus the growth of the market in the aluminum industry, discounting the natural growth of the construction materials market, might have a direct effect on the sales in the steel industry.

The examination requires a great deal of knowledge about economic conditions as they affect industrial conditions. It was mentioned previously that certain industries might be favorably and certain other industries unfavorably affected by certain economic changes. Government spending on national defense or on road construction will have different consequences and will affect certain industries differently. Thus, the various cross-examinations will have varying results in different industries.

A comparison between industry and industry figures might be extremely important for industrial enterprises in complementary relationship and, conversely, in supplementary or substitutive relationship with one another. A wage increase through nationwide bargaining in the steel industry might favorably affect the sales possibilities in the aluminum industry. The abolition of the tax on margarine might unfavorably affect the dairy industry. Tariff regulations, raising or lowering import and export duties on motor boats, for instance, might affect the motor-boat producer. Evidently, economic changes favoring one industry might unfavorably affect another.

A rise in industry sales might or might not also mean a rise in a specific company sales. A careful study of past sales of the industry and the company might reveal certain recurring inverse ratios. An observation of past years relative to industry versus company sales might, for example, reveal that when the total industry sales increased by 5%, the company sales volume increased by 10%. If this ratio appears to be a recurrent one, the company making the sales forecast can infer that an economic indicator which predicts a 10% sales increase for the industry as a whole might, in turn, predict a 20% rise in company sales.

OTHER FACTORS

Sales forecasting attempts to predict sales possibilities for the coming year on the basis of the past. In a dynamic industrial setting, however, other factors besides the past must be taken into consideration. Thus as new products are developed, some slips in sales are bound to take place. The question, of course, is how much. When Bufferin was introduced, the producers of aspirin had to revise the output of packaged aspirin to guard against a possible overproduction. When the electric shaver was introduced, the razor blade makers had to reconsider their future sales in light of this new development.

Advertising practices might also play an extremely important role in company sales. To some extent the company knows that its sales promotion and advertising budget rests on future sales; by the same token, an attempt to guess competitors' advertising efforts might be helpful in appraising the share of the market that can be expected. Advertising tends to raise sales of a given company's products at the expense of competing products. For example, to look at the cigarette industry from a nonsmoker's point of view, it appears that one brand of cigarette is not really different from another. Therefore, one cigarette company can make a wrong sales prediction if it disregards a competitor's advertising campaign.

Of course, no sales forecaster can take all variables into consideration. Even though a pending TV program is known to other producers, the sales resulting from the program depend on factors unpredictable in advance. Revlon's launching of the "$64,000 Question," for instance, was known to the other cosmetic firms; what could not be known was the program's extraordinary success. As a direct result of the program a marked improvement in Revlon's sales took place at the expense of other producers selling—for any practical purposes—identical items. Although the introduction of a new product is known to competitors, the public acceptance of the product is unpredictable. It might spread as a brush fire, but sales might also take a slow and gradual course. Thus, a sales forecast might turn out to be too conservative or too optimistic, depending on the possible oversight of an important factor.

Since these factors are unpredictable, the forecasting of a company might be affected by actions of its competitors; at the same time, the other companies might be affected by the action of the first one. Although in some industrial enterprises an unusual happening might cause a major disturbance in sales, in other segments of the same market it might have a negative effect.

All this explanation indicates that, regardless of how scientific the forecasting procedure is, guesswork about possible actions of competitors is bound to be an essential element of sales forecasting.

ACTUAL FORECASTING PRACTICES

Up to now principles and reasons for forecasting were discussed, in addition to the various forecasting techniques. The validity of the discussion must, however, be tested by examining the actual forecasting practices of various representative industrial enterprises. It must be apparent at the outset that the economic indices used to forecast the economic climate and the industry's sales potential will differ with the industry. Nevertheless, the method of forecasting apparently follows the general pattern already described.

Mechanics of Forecasting

A general observation of industrial forecasting reveals that most industrial forecasters use charts as working tools. The purpose of charts is, of course, not to look at pictures, but to visualize the trend which sales take so that conclusions can be reached without much fuss and trouble. It was stated[3] that two charts can be used advantageously; one for display and another for exploring ideas. On the work chart, seasonal variations or revisions of the forecast can easily be adjusted and substituted by another projection which seems more reasonable in light of current developments.

Forecasting in the Carpet Industry[4]

Forecasting in the carpet business must take the large variety of carpets (for example, over 1000 stock items) and the short pattern life into consideration and contrast them with the economics of long runs per pattern. To use facilities efficiently, each pattern must be available when the customer wants it. Immediate shipment is a must. In view of these characteristics of carpet making and sales, long-run production does not always seem compatible with making all patterns available at least cost. In order to stay in high-availability stock position, however, all patterns must be produced periodically. Which pattern should have the longer run, however, is difficult to know in advance; in fact, the only way to test consumer preference of a pattern is to make short production runs of all patterns. Economical production runs are not always possible because one does not know in advance whether it is worthwhile to turn out a large volume without some assurance of sales. On the other hand, if a pattern based on short-run production "goes like butter," the company is not in a position to ship because of having made only a few hundred yards to see what the customers want. Faced with these difficulties, the carpet companies must adapt forecasting techniques to their specific needs so that they learn in advance how much to produce from which pattern and to get, at the same time, the smallest cost of production.

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[3] A. Rosenbaum, "The Seasonal Sales Forecast," Special Report 27, American Management Association, 1957.

[4] H. B. Sprague, "Presentation and Review of the Forecast," *ibid.*

Sanford Carpets, a division of Bigelow-Sanford Carpet Company, Inc., makes a 12-month forecast from June to June. But a new forecast is being prepared for the next 12-month period in March. This not only permits a review of the current forecast but provides for changes if revamping becomes necessary. Actually, adjustments are being made every month. Thus, in a sense Sanford has a rolling forecast because the passage of each month precipitates some changes in the next month's forecast.

Through the Carpet Institute, the industry sale is known; the Institute reports actual monthly carpet shipments near the end of each month. Thus, based on past and recent records, a company can always compute its share of the market and have a pretty good idea about the quantity which it will be able to sell. The Sanford Carpet company takes 0.214% of disposable income to predict the share of carpet sales the industry will carry. The sales reported by the Carpet Institute can be used to countercheck the validity of this criterion. The above-mentioned 0.214% was established because the company found a strong correlation between industry's sales volume and the disposable income; even to the extent that a precise percentage could be established. Since this correlation was found, it is evident that the company must watch out for economic happenings capable of affecting disposable income. Because a change in the personal income tax would seriously affect disposable income, any such change would mean more or less carpet sales. In the same manner, an action of the Federal Reserve Board in any given Federal Reserve district would affect carpet sales in that district. Reference is made here to an action which would raise or lower the rediscount rate. A loosening of credit restrictions can accomplish two things as far as the carpet industry is concerned: 1) it might accelerate retail sales and 2) it might facilitate financing large inventories by retail stores which market the carpets.

Forecasting in the Automobile Industry

By and large, the automobile industry forecasts its sales by forecasting the general economic conditions, particularly disposable income. This bears some resemblance to the carpet industry. The main difficulty lies in the problem of determining the product mix, so that customers can obtain exactly the car they want without waiting too long for it. If a customer has to wait too long, the sale might be lost to a competing automobile company.

The basic problem in the automobile industry, then, is the appraisal of total industry sales. The automobile companies have often overestimated their sales potential; nevertheless, once the industry volume is established, each company knows from statistically evaluated data the share it will have of the industry sales. This then becomes the "standard volume," and all plant layout and tooling considerations are based on that figure. This is, of course, the target which the sales department must try to sell, because costs and prices are based on this figure. Anything sold above the standard volume makes extra profitability possible. It is essential, however, also to appraise what can be sold above and beyond the standard volume and how production can be kept on an even keel despite the fact that April, May, and June are heavy sales months relative to others and particularly relative to the winter months. To store surplus would be too costly, and for that reason most car companies work overtime and multiple shifts in preparation for high-output months and short hours and weeks during low-production months.

To establish the desirable product mix (important as it is to optimize sales at the outset) is a phenomenal problem because for any practical purposes the automobile industry mass-produces "custom-built cars." With the body styles, multiplicity of accessories, car types (convertibles, station wagons, two- and four-door sedans, etc.), it would be possible to turn out over 1.5 million cars without exactly duplicating any one of them. A proper appraisal of the product mix will make it possible to maximize volume in the early days after the introduction of the new model at which time there is no way of knowing what consumers will actually prefer. The dealer and the car manufacturer are at a disadvantage if the "style" or "styles" which turn out to be best sellers are not in the showroom ready for delivery. Both dealer forecast and home-office forecast must be carefully correlated in the interest of a profitable product mix.

At the end of the model run, just as at the outset, an accurate forecast of total run and mix is essential to prevent being stuck with millions of dollars worth of leftover parts and accessories. Barring provision for spare parts, the prediction of total sales and product mix must hit retail sales per model year almost on the nose. Any deviation from 1% of the norm would precipitate distress selling.

At the Ford Motor Company[5] the programming staff correlates sales with production capacity and with the various lead times (that is, with the procurement implications of parts). This group is closely connected with the market planning department, which tallies the grass-roots forecasts from 35 sales districts (monthly requirements as the districts see things developing).

Although the share of the market can be ascertained from a trend line, recent sales history is still of extraordinary importance. The combination of industry estimates and Ford's share of market results in a month-by-month projection of retail delivery needs; this is confirmed by the grass-roots forecasts. The forecast (statistics correlated with opinions of sales districts) is subsequently translated into a production plan providing proper allowance for fluctuations in dealer stocks and product mix. The latter is the most difficult part of programming, because a potential customer for a convertible, for instance, just does not want to buy a station wagon. For the above reasons, interim forecasts based on recent trends are the rule and not the exception; they fulfill the purpose of finalizing "style" runs.

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[5] E. H. Sonnecken, "Sales Forecasting in the Automobile Industry," Special Report 27, American Management Association, 1957.

Forecasting in the Pharmaceutical Industry

At Eli Lilly Company[6] production is based on a 5-year and a 6-month forecast of total company sales broken down into 30 product groups. The latter permits the calculation of plant-capacity utilization and the allocation of that capacity to different uses, the meaningful development of lead times, the attainment of finished goods inventory targets (quantity and deadlines) and the solution of other problems relevant to production.

Lilly firmly believes that the past is representative of the future. In the experience of the company, pharmaceutical needs tend to grow with both population and disposable income. Thus, a careful tab is kept on these indices. The share of the total industrial sales is a pretty closely recurring figure, and the company can take a known percentage of the industry total to determine the next year's sales. The question then is how the total industry sales can be arrived at.

Evidence supports the assumption that in the pharmaceutical industry every 10% change in disposable income, up or down, causes approximately 5% more or less business in the industry as a whole. Thus, the industry sales volume is arrived at merely by multiplying disposable income by the time trend. This product is subsequently translated into company sales figures by taking a predetermined percentage of industry sales into consideration. Accordingly, the industry volume multiplied by Lilly's percentage share of the market gives the dollar value of predicted sales.

The breakdown of total company sales into the 30 commodity groups is also based on past experience. Nevertheless, the prediction on the basis of past percentages is periodically revised, depending on the predicted total industrial sales, which, as already noted, is a function of economic forces. The regulating of production within each of these groups is a production control function. Production control relies, of course, on inventory records of stock items reaching minimum levels. The 30 product groups are expressed in requirements per package size. When plotted on a sales control chart, each item is kept track of and comparison is made between predicted and actual sales.

Forecasting of Electric and Gas Ranges

At Hotpoint Company, a division of General Electric Company, the forecast of sales of electric and gas ranges is merely a guide to production

[6] K. F. Griffith, "Sales Forecasting at Lilly," Manufacturing Series 216, American Management Association, 1954.

decisions.[7] Nevertheless, the forecast serves three equally important purposes. Each forecast is made for different units of time and by different methods and is predicated upon different assumptions. From the point of view of production, the long-range forecast is important to determine the depth of tooling and the acquisition of machinery appropriate to the predicted sales volume, in addition to determining the layout of the production line. The long-range forecast is, of course, equally important from the point of view of the short-term forecast. Whereas the long-range forecast determines the overall plant size and capacity, the short-range forecast fixes sales requirements in light of short-run output capacities.

As far as year-round production is concerned, the annual forecast at Hotpoint is the most important. Divided into a breakdown of 12 months, it gives the overall production picture. Within this, a further division is made according to classes of products and models. Although the yearly forecast is refined every 3 months, a month-to-month revision serving the purposes of production scheduling makes the former merely perfunctory. Here, attention is focused on the model mix, while in the long-range and the annual forecasts little, if any, consideration is given to the product mix.

The 12-months forecast predicts a trend line into which the yearly forecasts must fit as component parts of a jigsaw puzzle. Whereas annual forecasts reflect cyclical fluctuations and can move above or below the trend line, the curve is a smooth one from the point of view of the long-range trend line. The monthly forecast, in turn, is derived from the annual forecast, but it takes evident seasonal peaks and valleys, stock positions, and the backlog of orders into consideration.

Forecasting is done in steps. First, the sales of the industry as a whole and, second, Hotpoint's share of that total, expressed in percentages, are ascertained. This percentage (even if over- or underappraised) can always be attained, because a firm can "buy" its place into the industry by price policies, quality changes, advertising and distribution policies, etc. The forecast itself is in reality an aggregate of several partial predictions based on different factors capable of influencing sales. However, the forecast is always made on the assumption that the population and the standard of living will continue to increase, in addition to both national productivity and per capita income.

Classified into four groups (electric cabinet style, electric built-in style, the gas cabinet style, and the gas built-in style), each group is further split into units earmarked as replacements and as first-time acquisitions. Based on a statistical "scrapping table," the assumption is made that 3.5% of the ranges of 1960 vintage will be replaced in 1967. The scrapping table is a summary of information collected from the warranty card on which the customer states the age of the range that he traded in or replaced and, if the latter, what disposition was made of the old range.

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[7] W. S. Peterson, "The Importance of Both Long- and Short-Range Forecasts," Special Report 27, American Management Association, 1957.

There are periodic changes in the scrapping table, but they are negligible. While some people keep their ranges longer than thus estimated, the majority of people fall into patterns of action. At any rate, these statistical data indicate the potential replacement market and the potential number of first-time owners. The latter are based on the saturation quotient (the proportion of people owning a product compared to the number who might own one), which can be derived from measurements such as the percentage of people with electricity who own electric ranges. Because of its relative stability and consistency, Hotpoint can arbitrarily extend the trend line and thus indicate the probable future of sales. Though the number of electrically equipped homes tends to change with the passage of years, the probable change can be predicted with a great degree of accuracy based on new-family formation—which largely depends on the birth rate 20 years earlier—and the long-range commitments and plans of utilities (gas, electricity, etc.) furnishing the power to run these ranges. The predictable growth of disposable income, the trend toward the suburbs, new construction, and the change of certain population segments entering different income brackets, as well as many other factors, give excellent measurements of the "saturation quotient." When this slow-moving saturation quotient is applied to the forecast of wired homes, it becomes the forecast of first-time owners.

All sales to first-time owners and all replacement sales represent the long-range industry forecast. Based on statistical data, the percentage share of industry sales is indicated by the trend line and can be modified by the rigor with which Hotpoint plans its advertising campaign.

The 3-month forecast, a derivative of the 1-year forecast, is developed in the same manner as the annual forecast; in particular, it considers the current backlog of orders and the trend retail sales seem to take. By watching retail sales, ascertainable from the warranty cards, or the inventory position and actions of dealers (affecting the distributors), certain basic predictions can be made. Since from here on accurate and elaborate statistics are available, further actions are based on detailed statistical data. The 3-month forecast is directly used to determine starting and finishing dates both for assemblies and for parts manufacturing.

FORECASTING AT TIMKEN ROLLER BEARING COMPANY

To ascertain future production requirements, Timken[8] makes a forecast for product groups (industrial and automotive bearings, replacement bearings, rock bits, tubes, etc.) first in dollar value and then in quantitative

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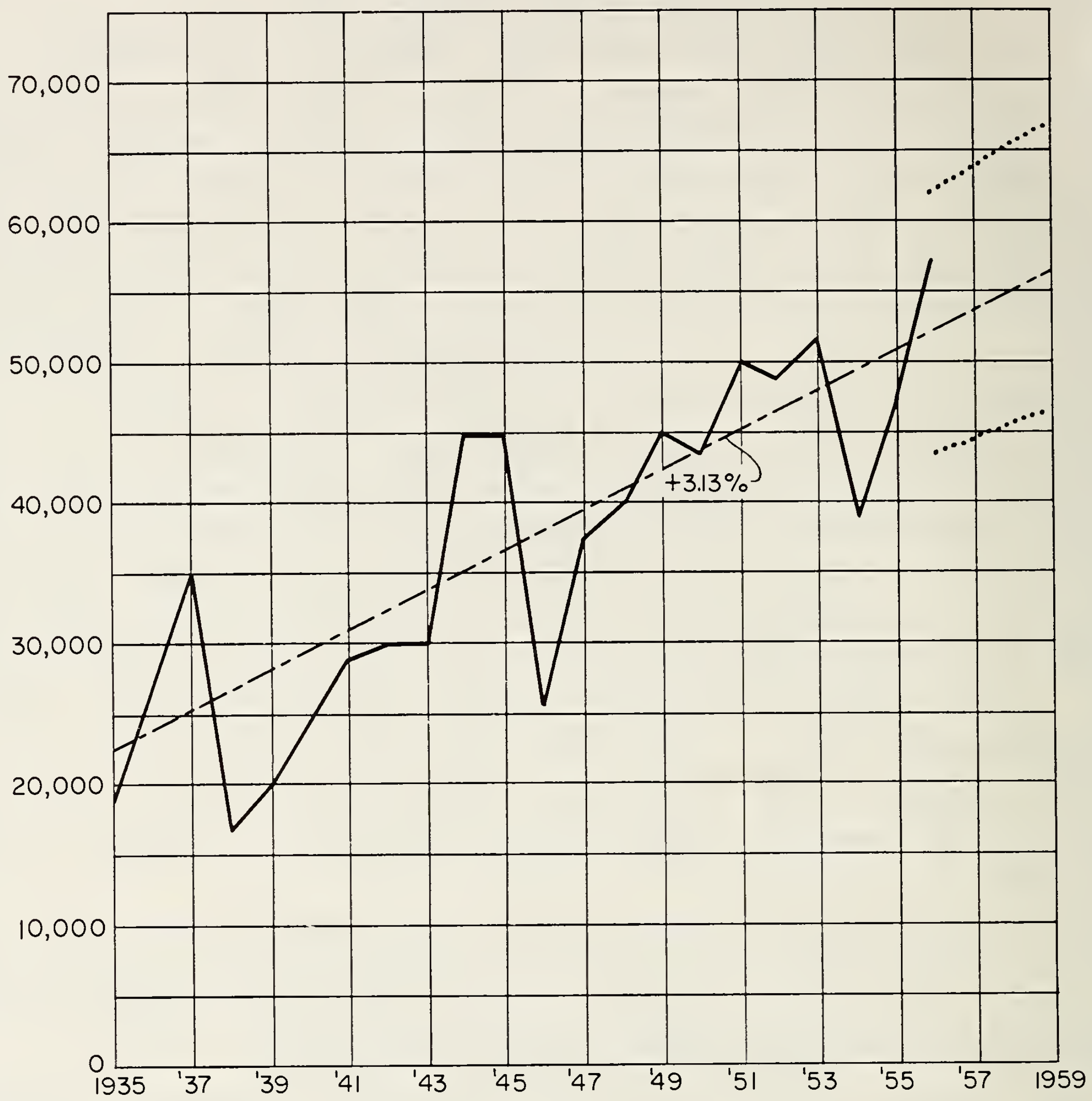
[8] R. E. Wagenhals, "Mathematical and Trend Analysis Forecasts," Special Report 27, American Management Association, 1957.



YEAR	
1935	18,774
1936	27,299
1937	34,602
1938	16,837
1939	20,127
1940	24,762
1941	28,661
1942	29,578
1943	29,453
1944	44,860
1945	44,872
1946	25,902

YEAR	
1947	37,295
1948	39,412
1949	44,613
1950	43,680
1951	49,614
1952	48,651
1953	51,862
1954	39,404
1955	46,973
1956	57,365
1957	
1958	

TRACKLAYING TRACTORS TITLE
NO. PRODUCED PER YEAR
INDUSTRIAL DIVISION SALES INDICATOR FOR-
FACTS FOR INDUSTRY – TRACTORS SOURCE
SERIES M 37 B
NO. OF UNITS PRODUCED PER YEAR UNITS-
1935 TO 1956 BASE YEARS
TREND LINE BASED ON YEARS 1947 REMARKS-
TO 1956 ONLY. GROWTH RATE BASED ON
1935 TO 1956 = 4.54%
TITLE TRACKLAYING TRACTOR PRODUCTION BASE –
1935 TO 1956

FIG. 10-1

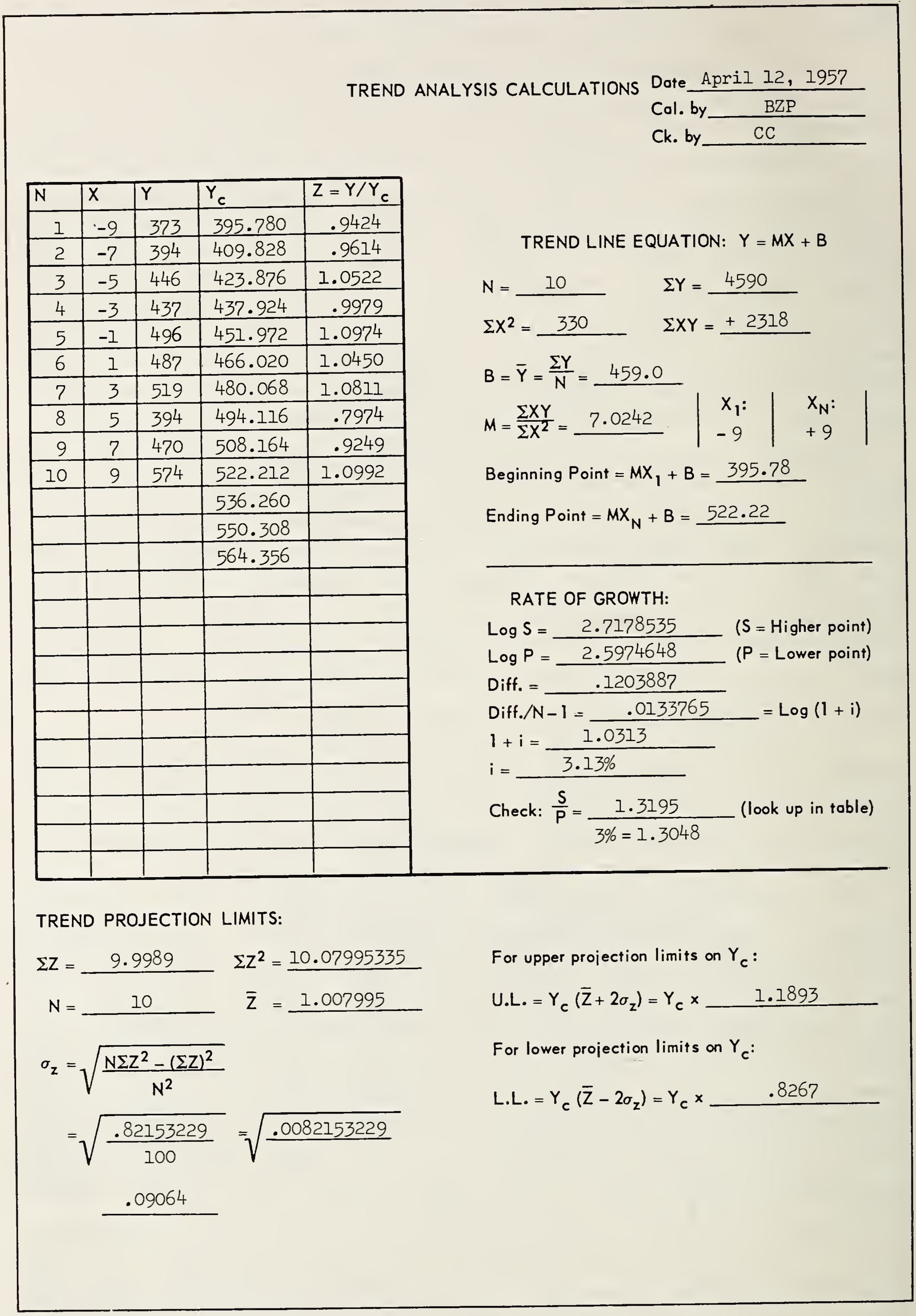
figures. The forecast is either the long-term (5-year) or the short-term prediction based on the poll, mathematical, trend, and economic analyses.

Timken's assumption is that buying patterns will remain in the future as they were in the past. Nevertheless, Timken Roller Bearing Company recomputes the various formulas which measure mathematical correlations every 6 months in order to minimize possible errors. The actual mathematical forecasting consists of ten steps, starting with prediction of sales for each division (based on past gross sales), seasonal adjustment and then comparison—with an IBM 604 computer—with selected indicators, that is, with certain factors capable of affecting sales. These factors, expressed mathematically, range from +1 to −1. (A perfect direct comparison has a mathematical of +1.0; a perfect inverse relationship has a value of −1.0.) The computer automatically selects the factor relevant to the product in question and applies the correlation coefficient to the predicted sales quantity.

Apparent from past experience is the high degree of interrelationship which exists between selected indicators (Federal Reserve Index of Production, manufacturer's sales, and machine tool index). Thus, if a class of goods has a high correlation value for one indicator, it will very likely also have high correlation values with the other indicators in the same interrelated group. The comparisons performed by the computer constitute the tentative forecasts several quarters ahead. By adjusting the tentative forecasts for share of market, price, or any other anticipated changes in business, the company considers the ten steps as being completed.

The mathematical analysis relies on the sales figures estimated (poll method) by marketing experts for the various product groups and on the results of the economic analysis. When the former are compared with the latter, the sales figures tend to be representative of sales because economic, trend, and industry factors were also taken into consideration.

For determining the trend line (used subsequently in the forecasting practice), Timken Roller Bearing developed an elaborate but streamlined system. An example which illustrates how the data is recorded and the trend line of tracklaying tractors is determined is shown in Figs. 10-1 and 10-2. The front of the form, Fig. 10-1, lists tabular data, description of the data, source, and the like, along with the chart. The back of the form, Fig. 10-2, gives an easy-to-follow procedure for computing the best fit in trend line, the rate of growth, and the limits within which the projected points should fall. It is important here to notice the X values. This calculation procedure must have the sum of the X values equal to zero, and X values must be evenly spaced. If there is an even number of Y values, the X series shown here is used. If there is an odd number of Y values, the middle X is 0 and the rest are + and −1, 2, 3, 4, on either side of the middle value. This form can also be used to handle negative rates of growth. The rate of growth is computed by solving for i in the compound interest formula:



TREND ANALYSIS CALCULATIONS

Date April 12, 1957
Cal. by BZP
Ck. by CC

N	X	Y	Y_c	$Z = Y/Y_c$
1	-9	373	395.780	.9424
2	-7	394	409.828	.9614
3	-5	446	423.876	1.0522
4	-3	437	437.924	.9979
5	-1	496	451.972	1.0974
6	1	487	466.020	1.0450
7	3	519	480.068	1.0811
8	5	394	494.116	.7974
9	7	470	508.164	.9249
10	9	574	522.212	1.0992
			536.260	
			550.308	
			564.356	

TREND LINE EQUATION: $Y = MX + B$

$N =$ 10 $\Sigma Y =$ 4590

$\Sigma X^2 =$ 330 $\Sigma XY =$ + 2318

$B = \bar{Y} = \frac{\Sigma Y}{N} =$ 459.0

$M = \frac{\Sigma XY}{\Sigma X^2} =$ 7.0242

X_1: - 9 X_N: + 9

Beginning Point $= MX_1 + B =$ 395.78

Ending Point $= MX_N + B =$ 522.22

RATE OF GROWTH:

Log S = 2.7178535 (S = Higher point)
Log P = 2.5974648 (P = Lower point)
Diff. = .1203887
Diff./N − 1 = .0133765 = Log (1 + i)
1 + i = 1.0313
i = 3.13%
Check: $\frac{S}{P} =$ 1.3195 (look up in table)
3% = 1.3048

TREND PROJECTION LIMITS:

$\Sigma Z =$ 9.9989 $\Sigma Z^2 =$ 10.07995335

$N =$ 10 $\bar{Z} =$ 1.007995

$$\sigma_z = \sqrt{\frac{N\Sigma Z^2 - (\Sigma Z)^2}{N^2}}$$

$$= \sqrt{\frac{.82153229}{100}} = \sqrt{.0082153229}$$

.09064

For upper projection limits on Y_c:

U.L. $= Y_c (\bar{Z} + 2\sigma_z) = Y_c \times$ 1.1893

For lower projection limits on Y_c:

L.L. $= Y_c (\bar{Z} - 2\sigma_z) = Y_c \times$ .8267

FIG. 10-2

$$S=P(1+i)^n$$

The factors used in the mathematical and the trend analyses come from government or other collecting agencies as well as from the trade association. The basic source is the marketing organization. To learn more about the statistics of sales forecasting, see Appendix E.

FORECASTING AT EASTMAN KODAK COMPANY[9]

Eastman Kodak forecasts by individual product groups which are given in quantity rather than in dollar value. The major methods are the trend, cycle, and the multiple correlation. This approach resembles forecasting of the Timken Roller Bearing Company. The next step is to modify the trend projection by an economic forecast. Thus the past sales of each product group are studied in comparison with various economic indicators in order to learn which economic factor appears to move in synchronism with product sales. Once the relevant economic factor is discovered and selected, a further study is made to determine the precise relation between changes in the economic index and changes in product sales. When plotted in chart form, sales quantity relative to an economic indicator such as disposable personal income will often reveal a regular pattern which can easily be projected for future years. A projected value for the ratio can then be converted into a sales forecast because the value of the economic indicator for that year is included in the economic forecast.

Once the economic forecast is taken into account, then numerous other factors capable of influencing sales in the interval ahead are examined and their influence on sales is estimated. These factors include changes in the competitive situation, current dealer inventories, sales and promotional plans, etc.

After the forecasts for every product group for one year ahead are developed, the planning group breaks down the aggregate quantity of the product group into data on each individual finished product according to size, kind, package, etc. The annual data in each category are then allocated to each period on the basis of seasonal indexes. The planned finished goods production and stock levels are then worked out.

Production schedules and inventory levels are reviewed each production period (that is, 13 times each year), and part of this review includes the sales forecast for the year. In each period, the sales forecast for the current year is reviewed with the major sales and production department groups. These preliminary review meetings are then followed up by a period review meeting of the finished products committee.[10]

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[9] Based on three different speeches.

[10] Excerpted from a speech of Edmund R. King on the subject of Techniques and Uses of Forecasts of General Business Conditions at Eastman Kodak Company, at the annual Meeting of the American Statistical Association. September, 1956.

FORECASTING IN THE TIRE INDUSTRY[11]

Lee Rubber and Tire Corporation makes industrial rubber products. Tire sales projections and production forecasts are made up for both short and long periods. A short-term forecast is reviewed quarterly from the industry standpoint and may for production reasons be reviewed in even shorter intervals. The procedure to arrive at final figures begins with industry performance to date versus the similar period in the previous year. The Rubber Manufacturers Association supplies the information on industry sales figures. These figures, provided monthly, indicate passenger, truck tire, and tube shipments as well as production and inventory build-up. The data are supplemented on a quarterly basis by a breakdown of tire shipments by size and type.

The data thus assembled are indicative of the future, but to double-check the figures, three other data will be used which tend to concur. These are 1) consideration of the number of cars for the future period which will be two years old or more (this indicates the replacement market), 2) the forecast of new car and truck production to establish an estimate of original equipment requirements of tire products, 3) determination of estimated export quantities and Federal government requirements.

When the industry demand is well established, the general economic conditions are considered. Those economic factors were selected which influence the three data listed in the preceding paragraph. It was discovered that there is a *direct correlation* between certain economic indexes and (2) and (3), but an *inverse relationship* between certain other economic factors (disposable income, curtailment of production in the automobile and truck production, etc.) and (1).

Since the Lee Rubber and Tire Corporation has a fairly steady percentage share of the market, reliance can be placed on it to arrive at company sales. However, since sales of tires follow very definite seasonal variations (while for practical purposes production cannot), the final decision on manufacture is based on the production planning department's ability to build inventories in slower sales periods to meet sales peaks which production capacity could not match. The master production plan therefore establishes monthly production quantities for each item classification and makes every effort to maintain a uniform daily production rate. Once established, the master production plan will remain unchanged, unless the sales outlook or inventory needs change significantly. However, in establishing a production plan, several factors must be considered: sales forecast, inventory requirements, productive capacity of the physical plant, manpower needs, etc. The physical plant capacity is relatively fixed within any one planning period, and any significant change in manpower requirements can be very costly.[12]

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[11] Material was supplied by H. K. Paxon for purposes of class discussion.

Forecasting in the Television Industry[13]

In view of the fact that the television industry uses an approach to sales forecasting and production planning that is similar to the one used in the range and electronic-oven industry (see Hotpoint's forecasting method), the following is merely an outline of Radio Corporation of America's forecasting practices. However, this is only one of the many methods used in the production planning of various production lines at RCA. This applies only to TV set production.

1. Industry forecast for TV sales is arrived at by a) review of historical unit sales of industry from reports received from the Electronics Industry Association (EIA), of which RCA is a member, b) preparation of index reflecting seasonal patterns, c) determination of cyclical patterns, d) review of data and chart by month such information as long-run trends, 12-month moving averages, actual data, percentage relationship of latest year to other years or group of years, percentage changes from other years, seasonal and cyclical patterns, the nature of the replacement market for TV sets, first-time buyers, second-set buyers, etc. All the above information will give the company a forecast pretty much representative of future sales. Thus, TV sales are forecast purely on a statistical basis.
2. Development of indices reflecting economic factors and trends such as consumer income (spending for durables, nondurables, discretionary spending, etc.), gross national product, and certain national income factors.
3. Reviewing of housing starts, sales for automobiles, appliances, etc., general business inventory status for the economy, productivity, unemployment data, etc.
4. After having collected all the information listed above, the statistical forecast is reconsidered in light of the various economic considerations to arrive at revised TV production units for the industry.

Since RCA knows, from statistically recurring percentages, its percentage of the total market as far as TV sets are concerned, the total sales figure is multiplied by the trend-line coefficient to arrive at RCA's annual sales for television sets. For the monthly forecast the annual sale is divided by 12, which gives the average monthly production rate. Finally, the latter is multiplied by the appropriate seasonal index (developed on the basis of past experiences) for each month, which gives the monthly production forecast. However, for operational purposes, this must further be broken down into product mix (black and white, color TV, screen size, cabinet type, etc.). Dealers' and distributors' statements as given by the various sales districts are also evaluated and used in the final decision making. The problem is, however, relatively minor because not a great deal of difficulty is experienced when changeover from this model or that is contemplated. However, belated information could cause shortages in certain parts used in specific models but not in others.

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[12] Supplementary information was furnished by Mr. F. L. Hopper of The Firestone Tire and Rubber Company.

[13] Material was supplied by J. W. Andruszko for classroom purposes.

FORECASTING IN THE LIGHTING PRODUCTS INDUSTRY[14]

In the experience of Sylvania's lighting division, sales forecasting is the responsibility of high-level representatives of the departments directly affected by the sales forecast. Therefore, all short- and long-term forecasts are the result of the combined thinking of the sales forecasting committee, consisting of representatives of the sales, control, and production planning functions. The latter department's function in sales forecasting becomes paramount considering the fact that it is responsible for establishing uniform levels of production, inventory, and employment.

A member of the sales analysis department gathers facts, figures, and trends for the committee to review and evaluate. Historical data regarding industry volume, Sylvania's share of this market, percentage changes in volume, seasonal patterns, analysis of general business conditions, and preliminary estimates are presented to the committee.

The committee meets monthly, and it normally concentrates on forecasting for the following 3-month period. The result of the meeting is an official division sales forecast which is issued monthly and reflects year-to-date actual sales and forecast figures in units and dollars for the remainder of the calendar year. By totaling the year-to-date sales and forecast figures, Sylvania is able to show the going rate of sales by products for the year.

Because one of the most important uses which is made of the forecast concerns it, the production planning department has representation on the forecasting committee. The production planning department uses the forecast as a basis for factory production schedules. Since the forecast is general in nature, the problem of the production people lies in determining the product mix that is anticipated in future months.

As an aid to the production planning department, the tabulating (IBM data processing) department, through the use of punch card equipment, issues an "available inventory." This report, which is run off for each major lighting product (incandescent, fluorescent, mercury vapor, fluorescent starters, photoflash, projection, flood and enlarger, etc.), indicates for any given month the output, the orders, and the available inventory over and under minimums or the actual inventory for a prior month for each type of lamp falling within each of the above product classifications.

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[14] J. Donald Powers, Sales Analyst, Sylvania Electric Products Inc., Salem, 1958. The material was furnished for purposes of class discussion.

The available inventory for a given type number (all lamp types are coded by number) which is printed on this report is calculated by an electronic calculator. This machine adds the beginning inventory, current month production and inventory adjustments, and then deducts the unfilled orders from the previous month and orders from the current month. The result of this calculation is a revised, "available inventory" figure. The over and under minimum for a given type number is predicated on how much over quota, percentage-wise, the available inventory is. It follows, therefore, that if the reverse situation existed wherein the quota exceeded the available inventory, that particular type number might be in a "light" inventory position. The minimum quotas, although predetermined, are of a flexible nature and therefore subject to change depending upon the demand for a given type number.

The sales forecast, the available inventory report, and knowledge of current and future orders, coupled with the judgment of production analysts, are the basic ingredients of Sylvania's production planning.

FORECASTING IN THE COSMETICS INDUSTRY[15]

Revlon Incorporated, an important producer in the cosmetics industry, employs standard methods of sales forecasting, in spite of a continuously changing condition characteristic of a high-fashion industry. The forecasting methods include 1) the long-range production forecast and 2) a revolving quarterly forecast. In the former, based on a "budget" sales forecast for a 6-month period and prepared by the sales and marketing division, the 6-month level of activity is predicted on the basis of performances as indicated by corresponding years and months in the past on the one hand and economic conditions and promotion plans on the other. The budget sales forecast is an aggregate opinion of men in the various sales districts—men who know the field and are acquainted with general economic conditions. Their prediction classifies items and quantities by months.

For month-to-month operations Revlon prepares a revolving quarterly planning forecast. This means that each month Revlon issues a forecast for the ensuing three months, by month, defining items and quantities. With this instrument Revlon is able to reflect sales trends, promotions, and new product introductions on a very current basis. This planning forecast is prepared by the operations planning group, working independently of the sales and marketing groups. The operations planning group works from up-to-the-minute sales tabulations and projects trends and seasonal patterns as they develop. Thus, the function of this department is based on the science of statistics and quantitative measurements in general. This forecast, coupled with the budget sales forecast, provides the basis for both production and the closely related purchase planning.

Revlon's monthly production planning is to provide for inventory replenishment of regular items, in addition to serving other purposes falling outside production. In the operating departments, Revlon schedules for production approximately 750 items of a finished goods inventory of an average of 2 months coverage (based on an average forecast through 6 months). In other words, Revlon works from a minimum 1 month, which is the reorder point, to a maximum of 3 months. This indicates a production of 2 months supply of any given item that is being produced repetitively and to a 1 month supply, within a month, for those items that are being produced continuously.

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[15] The material was made available by L. G. Pacen, Vice-President of Manufacturing, Revlon Incorporated, for purposes of class discussion.

A production plan is prepared each month for the ensuing two months to the following:

Requirements (a) planned inventory
(b) forecast sales
(c) special requirements for two months ———
Total requirements ———
Less inventory on hand ———
Net production requirement

In this fashion Revlon continuously brings its production requirements in line with sales take-away and reviews each item every month, although only approximately 50% of all items will be at a "to order" level.

Actual scheduling of the plants' activity is done on a week-to-week basis, so as to best utilize company production facilities, cope with variables in material deliveries, and yet produce the products and quantities detailed in the production plan.

Forecasting in the Snow Chain Industry[16]

In the snow chain business, the manufacturer must have chains available wherever and whenever it snows so that when the jobbers sell out or deplete their stocks, they can replenish them from nearby warehouses. The objective is, of course, to sell as many chains as possible during the snow period. In order to prevent potential losses in sales, the manufacturer must carefully control both his consigned stock inventories and his warehouse inventories so that in the event there are several consecutive seasons with no snow, he does not suddenly find himself with his operating capital tied up in nonmoving inventories in the field. Hence, it is essential to use past experiences and records retained over the years as a measure to forecast sales and production in order to assure a reasonable turnover on his capital.

For reasons previously indicated, the manufacturer must forecast his sales for the coming season and set up his production schedule accordingly. For this purpose, all consigned accounts and warehouses submit each month an inventory of stocks on hand and a report of sales from that stock. Hence, the manufacturer knows exactly what has been sold from each account and warehouse and what stock still remains on consignment and in each warehouse by type and size.

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[16] The material was made available by Roland Erving, Manager, The Chain Division, The McKay Company, Pittsburgh, Pa.

The preceding data are used in the prediction of future sales. Past records indicate the typical sales quantity of past years. Statistically speaking, they are recurrent, but geographically they are not. Further data needed include plant inventory at beginning of season, plant output during season, shipments to consigned accounts during season, shipments to warehouses during season, shipments to open accounts during season, present plant inventory, etc. Although the economic conditions will influence sales in view of the fact that, with rising standard of living, more vehicles are on the road, the economic conditions are not significant enough to go beyond the ordinary scheduling problems described above. Consequently, in the tire chain business little attention is paid to basic economic changes. Nevertheless, if the records reveal a rising volume of sales, that is taken into consideration at the time the schedules are determined.

For the coming season, forecast is made at the beginning of the year rather than waiting until the final figures are in—which may be in about the middle of April. The reason for this is that the manufacturer must have most of his production completed by October of the following season to enable the processing of incoming orders, say, as of April. These might call for minor differences, but they create little problem in view of the fact that the product in question is industry-wide and the variations are insignificant. Production adjustments can be made in April or May to conform to any changes in the forecast as reflected by the tail end of the seasonal figures.

By forecasting early, the manufacturer assures himself against loss of production during the months of January, February, and March. If production were lost during these months, it would have to be made up in the following months and would include the added cost of overtime, plant downtime (that is, equipment amortization), interruptions in the flow of production etc. The early forecast assures a steady and even production every month.

Based on all of this information, the sales department forecasts sales for the coming season. Subsequently, a production schedule for the plant is set up. It is up to the production planning department to determine the product mix. Both the sales forecast and the schedules are made in pounds. This is a customary thing because the raw material (steel) is bought on a tonnage basis. Therefore the plant also produces on this basis. Since careful records of the past are kept (by type and size), the production people know in advance that if so many hundred thousand pounds a month are scheduled, the total output should represent x percentage of each type and size. Since these percentages tend to change with tire size changes made by the truck and automobile manufacturers, it is possible to keep up with any current changes by following the reports of vehicle producers. Hence, there is little obsolescence in inventories.

FORECASTING IN THE BAKING INDUSTRY[17]

In view of the generally stable nature of demand for baked products, the sales forecast is made for a 3-month period. The sales in dollars of the previous year are compared with the sales in some other years preceding the last one. Periods corresponding with recent months are compared with one another. A ratio is based on these two comparisons. Then the sales prediction for the forthcoming period is based on the ratio which was established. The sales are then further divided into 30% cake and 70% bread. These are the customarily recurring percentages regardless of the sales volume achieved.

To exemplify the forecasting practice in the baking industry, let us assume that the sales for the period of July to September, 1961, were $1,000,000 and that the sales for the same period in 1962 were $900,000. There the ratio is 10:9, which is then applied to the sales figure for the period October to December, 1961. Assuming the latter is $1,500,000, we have a sales forecast for the corresponding period 1962 of $1,350,000, which would mean an expected dollar value of sales in bread of $945,000 and cake of $405,000.

THE VALUE OF ACTUAL CASE DESCRIPTIONS

To avoid hypothetical situations, various case descriptions were selected from paraphrased direct statements of executives to give the student an opportunity to see, in the different fields of industrial endeavor, the variations in sales forecasting practice. At the same time, the student should notice that the general concensus of methods does not differ from the "theoretical."

The first few companies placed considerably more emphasis on the economic forecast than the last few. If the student considers the nature of the products in question, the reason for the emphasis becomes apparent. Some goods depend largely on "surplus" money, whereas others are purchased as need arises (automobile snow chains, bread and baking products, incandescent lamps, etc.). Thus, the latter producers use primarily a statistical approach, and secondarily an economic forecast. Producers of "luxury" items develop an accurate economic forecast because the sales volume is largely dependent on economic conditions.

However, it has been amply demonstrated that sales forecasting is the the basis for production decisions. It appears to be so important in many companies that top management makes the decision even though the technical details possibly originate in the research, economics, sales, or market research departments.

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[17] The material was supplied by Mr. Charles Smith, Manager, Ward Baking Company of Pittsburgh, Pa.

SUMMARY

Sales Forecasting in Continuous Production

The purpose of sales forecasting in continuous production is to provide both sales and production management with factual information about future sales. Because no continuous producers decide on the output after orders are received but produce to supply an unknown market, it is essential to analyze certain factors causing sales to go up or down in order to predict the possible sales volume. Production must then be geared to this sales prediction.

Sales forecasting is necessary because a continuous producer must know in January what will be produced in May in order to tool up (which is largely a function of the sales volume) and place purchase orders for May delivery sufficiently ahead of time to have assurance of delivery. It would be impossible to wait until the last minute. A late start might mean a late arrival on the market. And in competitive business, the latecomer cannot sell because others have already flooded the market. No large-scale producer can afford to be caught short of supply, because it would mean loss in sales for him. By the same token, no continuous manufacturer can afford to produce in excess of market demand because of prohibitively high storage and inventory carrying charges and because a surplus might precipitate distress sales at cut-rate prices.

In order to make a profit in continuous production, it is therefore essential to assess the possible sales volume as accurately as possible. Improper appraisal of market possibilities can lead to either over- or underproduction.

Although many job shops also forecast their sales, in intermittent job shops sales forecasting is not as much needed as it is in continuous or repetitive production, if indeed it is needed at all. The producer of a mass product evidently would not know how much to produce and by which particular calendar date to complete production if a sales forecast were not available.

In the final analysis then, in mass production, the sales forecast ultimately becomes the monthly production schedule. First the yearly sales potential must be appraised, and then the yearly potential is broken down into monthly output requirements. The forecast serves as the basis for scheduling the production of parts and establishing material arrivals in line with the rate of assembly. As long as everything is planned well, output will match the sales volume.

The continuity of flow in mass production depends on the proper allocation of plant capacity, on the adequate maintenance of raw material flow, on in-process inventory levels, and on employment. The continuity of the flow of production will in turn determine the cost of production and company profitability.

METHOD OF SALES FORECASTING

The forecaster can either base his forecast on the segments as they relate to the whole or break the whole economy down into segments and arrive at a sales prediction by doing so. Some companies like to build up their sales forecasts from small geographical segments. Those who use this method rely a great deal on the opinion of the salesmen in the various sales territories, the judgment of the district sales manager, and finally, on the judgment of top management. While the forecast based on the opinion of men in the field has some merits, it has one major pitfall: it tends to neglect the important effects of the economy on each individual business.

The advantage of the second method (basing the forecast on expected economic conditions) is that sales are ultimately determined by the overall economic climate. If the prospects the economy has in store for each industry have been ascertained, the chances are that each firm can see itself in light of the sales possibilities as far as industry as a whole is concerned.

The breakdown is then as follows:

1. Economic forecast (recession, recovery, boom)
2. Industry forecast
3. Company's sales forecast

Evidently, if the economy is going to prosper, the chances are that the industry will prosper also. This is, however, not a necessary corollary. Therefore, the forecaster must be careful in selecting only those economic indices which are actually indicative of the well-being of a certain industry as a whole. A comparison of economic happenings and the potential industrial activity within the framework of the economy will cast a shadow indicating to some extent what a company might be able to sell. Each mass producer has his customary share of the market based on past data and the recurrence of each firm's percentile share of the industry's total output (sales). Expected industry sales can give clues to the firm's sales possibilities; thus the company sales data must always be evaluated in light of expected industrial sales also.

The difficulty with forecasting is, of course, that the data necessary for making the prediction are not readily available. Whereas the data on company sales, which also contain the breakdown according to product mix, are in most cases available, information on industrial sales is considerably more limited. Often it is impossible to find out about the exact size of sales and hence impossible to reach a conclusion on one's own percentage of industry total. To alleviate this difficulty, it is customary nowadays to belong to a trade association which without revealing the name of company collects sales information. With the information published in the magazine or bulletin of the association, most companies can readily appraise their own standing in the industry. Of course, the information is not as carefully broken down as one wishes it would be, nevertheless it is a great help in appraising one's percentage sales relative to the total industrial output.

The same difficulty exists with economic data. They are available, all right, but they must be carefully interpreted in order to arrive at valuable conclusions. The Federal Reserve, the Bureau of Labor Statistics, and many other private and governmental agencies collect and distribute economic information capable of serving most continuous producers in their forecasting efforts.

QUESTIONS

10-1. What is sales forecasting?

10-2. What is the purpose of sales forecasting as far as mass production is concerned?

10-3. How important to the repetitive, continuous, and intermittent producer is the forecast of sales volume for the next year, the next 5 years, and the next 10 years?

10-4. What are the financial consequences of overproduction or underproduction in highly competitive mass-production industries?

10-5. What makes forecasting possible?

10-6. What is the primary role of statistics in sales forecasting?

10-7. What are the two basic approaches to sales forecasting?

10-8. In connection with Question 7, explain which approach you prefer and why.

10-9. Can judgment be fully eliminated from sales forecasting by relying on statistics? Explain.

10-10. What is the statistical procedure in sales forecasting?

10-11. What kind of information must be gathered in different industries to make a valid sales forecast?

10-12. Where can the needed information be found to develop sales forecasts for the industry?

10-13. What use must be made of accumulated data in company versus industry forecast?

10-14. What are the various economic factors which must be taken into consideration in the tobacco, appliance, shoe, cement, and container industries in order to arrive at a fairly accurate forecast?

10-15. What function is assigned to charts in the development of sales forecasting?

10-16. What characterizes the sales forecast of a fashion industry where novelty is the rule and past sales might not be representative of the future?

10-17. Can you make a reliable sales forecast without knowing something about economics, statistics, and mathematics? Explain.

10-18. How can present methods of sales forecasting be improved upon?

PROJECTS

10-1. Select an industrial enterprise engaged in mass production and speculate about the sales forecasting procedure of that enterprise, but do not select one already described in the chapter. Secondly, speculate on the possible method used to break down the forecast sales volume into production schedules and into product mix. Finally, write a letter to the company in question, either to the public relations or production department, and find out the actual sales forecasting procedure which the company uses to determine its production schedule. The comparison of your speculation and a statement from the company can be very enlightening.

10-2. Assume that you are the manufacturer of fountain pens. How would you determine your next year's and next month's production capacity to make the required (that is, decided) output so that your overall costs are kept at the absolute minimium? What information do you need to set up your production program and how would you go about gathering the needed data? What would you do with the accumulated data? (Indicate correlations, trend lines, product mix, and breakdown considerations.)

10-3. State the relationship between advertising, sales forecasting, and production volume. Indicate also the function of sales promotion in mass production.

10-4. Develop a system capable of arriving at sales volumes with the help of statistics and mathematics in general and with linear programming in particular. (More details about linear programming are given in Chapter 15.)

10-5. Based on your knowledge of the principles of industrial organization, indicate the proper position of the sales forecasting function in mass production industries (firms). With what kind of responsibility and authority (if any) should the forecaster be endowed, and to which specific department should it be subordinated?

CASES

10-1. The Cigarette Company, Ltd.

The CCL was founded in 1911 when the giant American Tobacco Company was divided into smaller competing units as a result of an antitrust suit.

Whereas it originally confined its operations to the Canadian market, the success of its Adorable and Bargain—blended cigarettes—around World War I in the cigarette field and Xavire brand in the pipe tobacco field guaranteed a steady market in the United States and abroad.

In order to capture a certain share of the market, each firm, being in severe competition with all other tobacco firms, developed certain blends of cigarette or pipe tobacco. The idea behind a special blend has something to do with the habit-forming characteristics of cigarette smoking. If the consuming public gets accustomed to a certain blend, habit will assure a perpetuation of demand.

During the decade of the 1960s, the CCL added to its line of products by introducing first the regular menthol and later the king-size menthol. In the pipe tobacco field Mormon Poo and Zanzibar and in the chewing tobacco field Rutledge were introduced.

In recent years, despite the success of the tobacco industry as a whole, profitability of the Cigarette Company, Ltd. was seriously impaired. The appreciation of the stock values of most tobacco companies took an upward trend while the stock price of the CCL gradually, but steadily declined. Evidently, company management had to spend a great deal of time in soothing irate stockholders instead of focusing attention on important corporate matters. To pinpoint the source of the problem or problems, the board chairman–president of CCL called a meeting in which he stated among other things:

"The time has come to do something about profitability! While I hear from you, gentlemen, that our sales volume goes up year after year, paradoxically enough our financial position year after year becomes more critical and our profit margins tend to melt away. What we've got to do from now on is to make sure that whatever volume of sales we have, it is profitable. And neither we nor anybody else is going to be able to do that by just looking at growth projections. Sure, we may push our volume of sales to higher and higher levels, but as long as we push with it our costs of making tobacco products, we are not a bit better off than we were before. Whatever the cause of our difficulty—which we will soon find out—in forecasting, production, or inventory management, something's got to stop right now."

The seriousness of the situation precipitated investigations of all sorts. In the office, no one knew any longer who might be an investigator. But, sure enough, results started to come in and, when subjected to careful analysis, almost all, if not all, mistakes could ultimately be traced back to either under- or overproduction. Accordingly, when the company was caught short of a favored brand in high demand, profit possibilities were not exploited and unit costs were higher than they should have been, thus preventing the CCL from earning as much profit as it could have earned. The higher-than-normal unit costs narrowed the already thin profit margin; that is, the salable volume compared with the actual sales volume when prorated in terms of "implicit" costs indicated substantial savings possibilities, but of course the company did not take advantage of them. Also, the inherent loss in "potential" profits has adversely affected company earnings.

When more was produced than the market could absorb, the surplus had to be stored much longer than otherwise would have been necessary. Prolonged storage to some extent affected the quality, despite the cellophane packing. If less was produced than needed, the leaf tobacco was stored many months longer (see Fig. 1), which added to the costs of storage in addition to tying up $60 to $70 per 100 pounds. Occasionally several million pounds might be in storage.

FIG. 1. Inspection of redried tobacco leaves prior to blending. (Courtesy of the Tobacco Institute, Inc.)

The CCL was engaged in continuous production of several blends of cigarettes and pipe tobacco. Since labor was required primarily in the handling of the leaf tobacco (during the production process), the preponderance of manufacturing costs were chalked up by capital costs which fluctuated between 30 to 45% of total costs. Depending on the price of flue-cured, damp-cured, air-cured, etc. golden-yellow smoking leaves, material costs varied. Generally speaking, however, material costs were customarily twice the size of prevailing labor costs. The depreciation of equipment was evidently an important cost factor. If machinery was constantly in use, the plant could turn out 1500 to 2000 cigarettes per minute. Cigarettes represented approximately three-fourths of CCL's production.

In the preparatory stages, leaf tobacco went through a stemming operation in which a machine removed the midrib. Although operators monitored production,[18] cigarette making was nearly automatic. The presence of employees was required merely to remedy the situation in case of a machine breakdown. Employees were assigned to see to it that machines remain in continuous operation. After the stem of each leaf of tobacco was removed, tobacco leaves were sliced into hair-thin strings. From here the tobacco was moved with the help of conveyors to the blending station where various types and grades of tobacco met and were mixed. Mixing was necessary because no two piles of tobacco leaf can be considered alike. There are a top side and a bottom side to any grade. The mixing machines (filled with different grades of cured and foreign-raised tobacco), homogenized and blended the tobacco into a desired tobacco mix. It was essential first of all to determine the exact proportion of each ingredient in order to come out with the right blend for each purpose. Uniformity of "taste" was important to fulfill the company's advertising slogan "Sweet as a mother's love."

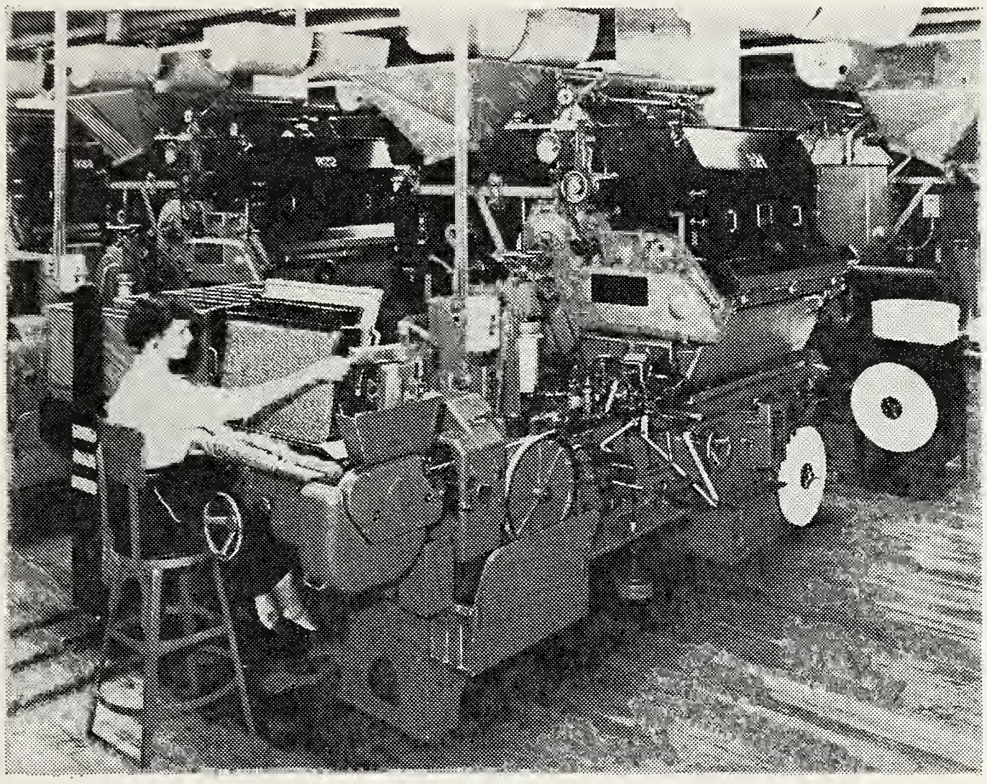

FIG. 2. Cigarette-making machine. (Courtesy of the Tobacco Institute, Inc.)

The cigarette-making machines (see Fig. 2) receive—by a belt conveyor—the blend tobacco from the blending stations and roll it into long continuous rods. These are cut into cigarette length. Subsequently, the cigarettes are automatically counted, packaged, sealed, and placed into cartons and shipment cartons in a series of continuous operations (see Fig. 3).

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[18] One of the main tasks of the operators of cigarette machinery is inspection—catching the imperfect cigarette or package of cigarettes.

Because of the substantial investment in capital equipment it was advisable to utilize plant facilities close to 100% in order to cut unit costs. Yet this at CCL seldom has been fully accomplished. Thus, overall utilization of production facilities was closer to 70 or 80%. The problem of recovery of capital investment was aggravated by the rapid obsolescence of capital equipment. Concerning this problem, the following excerpt has been taken from the board chairman–president's talk:

"If we compare the 50-cent profit dollars of today to the 100-cent dollars that were invested into equipment 10 years ago, our profitability is not quite as bad as it appears on the surface. Nevertheless, our competitors apparently know how to wear out equipment faster than the "progress" of obsolescence. Since nothing can be done about the government's depreciation policy, possibly except lobbying, it would be futile to lament the inadequacy of depreciation. Rather, we must fight bad with good and use equipment at such a rate that we get an amount of mileage out of it equivalent to our actual capital costs."

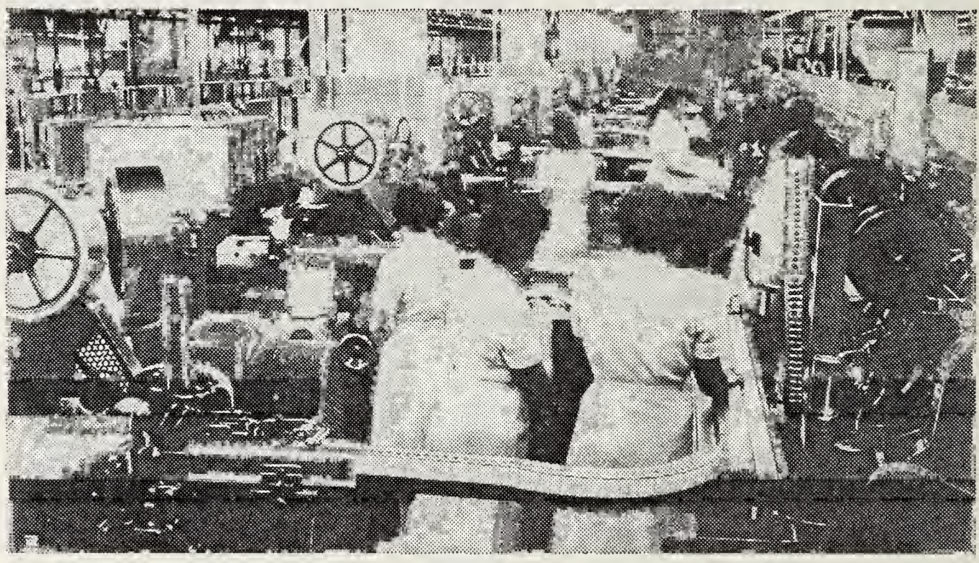


FIG. 3. Filling and packaging of cigarettes by high-speed machines. (Courtesy of the Tobacco Institute, Inc.)

While company management has succeeded in raising the volume of production year after year, production was fluctuating too much because of faulty or apparently faulty appraisal of demand for given blends of cigarette, pipe tobacco, or chewing tobacco. Thus, output often outran consumer demand in one month and fell short of demand in other production periods. In the former situation it was essential to spend large sums of money to advertise and to deplete accumulated inventories. It was, however, discovered that the combined costs of advertising and sales promotion, as well as storage, were greater than the savings brought about by the larger production volume. It was stated that the cost of advertising were out of proportion with the added "marginal" output and revenue. Also, while concentrated efforts were made to get rid of surpluses, production had seriously been curtailed; yet shortages were almost invariably noticed in an immediately subsequent period.

Production superintendents insisted that they did their very best to keep costs down, but that, since 1955, they had no longer been permitted to follow their own "hunches" to make a product mix that would accomplish production with the least cost. Since the introduction of the statistical department which handled the sales forecasting, the various plants were instructed to follow the sales forecast and always schedule the brand which was most in need at the time. This, however, meant frequent changeovers at the various work stations and precipitated constant switching of product brands and frequent interruptions of the continuity of production. It was informally estimated that because of such interruptions, production capacity was cut from 100% to 75% or less. In other words, with the interruptions resulting from the "foolishness of sales forecasting," machinery could seldom be kept busy longer than 75% of the time.

According to the present sales forecasting practice, the company's statistical department (sales forecasting) evaluated the market based on carefully collected statistics about sales, economic happenings, and changes in industry share of the market. The latter was 10% as far as CCL was concerned, but it could be raised with additional advertising to 12% or even to 13% if it were necessary. Industry sales rose year after year a given percentage, usually around 3%. In 1960 they rose 3.5% over the previous year. Out of the 507 billion cigarettes which were sold in the United States in 1960, the Cigarette Company, Ltd. sold 50 billion, but its sale in the international market has been reduced to 3% as opposed to the 17% which it had in previous years. This might be attributed to the increased competition with foreign producers in their own markets. This is significant because all this happened in spite of the overall increase (5%) of the international tobacco market.

Although considered in the forecasting procedure, the effect of government's tax policy on cigarettes sales was not always taken into consideration with sufficient care. State taxes on cigarettes now average 5 cents a pack, while the federal tax adds a further 8 cents to a pack. In some areas, local governments also impose a tax. The tax rate is considerably lower on overseas markets in some places of the world, and considerably higher in some other places than in the United States. How the tax might affect sales of cigarettes might be revealed by the fact that while the farmer averages about 65 cents on a pound of tobacco (approximately 18 packs), the various governments get $2.34 from the tax on the same tobacco. The sales forecasting department claimed, however, that since smoking is a habit, taxation does not affect sales enough to really worry about it.

The sales forecasting department, based on the above data, determined the possible yearly sales forecast and divided it into 12 monthly installments. It was up to the scheduling department to determine the schedules for the product mix in accordance with customary blend ratios. The trouble was, however, that the forecast was revised (the monthly forecast) so frequently that the machines had to be reset and rescheduled much too often; thus, it did not permit continuous flow. Constant schedule changes were certainly not welcomed by the various production superintendents.

The sales prediction was approved by top management and the approval was turned over to plant management for execution (this was their authorization to make whatever was needed). The revision of schedules was brought about by the reported output of each previous month as derived from reports of the Tobacco Institute. According to the sales forecasting people, it was cheaper to reshuffle schedules than to institute crash sales and advertising programs to deplete inventories.

The production people disagreed with this view, claiming that it was the cause for the lack of company profitability. They felt that if top brass authorized the old practice of letting them decide what would be produced, they would always have low-cost operations and the desirable product mix available in adequate quantities to meet the demand. One of the superintendents stated: "We cater today too much to the taste of the consuming public, instead of making the public like what we make."

Production experts felt that if they had produced cigarettes and other tobacco products as they saw fit (from their production perspective), production runs on any given blend would be longer, nevertheless, the market would always be supplied with any kind of brand (of tobacco product). Although storage costs would be somewhat higher, costly crash programs of sales promotion would no longer be necessary. The sales department should merely shift the advertising program from "pushing" one brand instead of another. A telephone call to the account executives would do the trick, and as long as sales promotion and advertising were blended in with production, sales and production would always match each other. One of the superintendents contended that profits began to decline in 1955 when the company changed from the above policy to the present one. It may be a coincidence, but it would certainly be worthwhile to investigate the possibility.

Other men in the company attributed the problem to the unwise purchase-storage policy on leaf tobacco. It was contended that too much money was tied up in leaf. They intimated that sales forecasting pays attention only to finished inventories, whereas the source of losses might well be in the raw tobacco area. A new inventory control man wondered why it is necessary to store, for a year or so, large volumes of raw tobacco. Where he came from (the electrical appliance industry), no one would think of keeping such large sums of money in idle inventories.

Inventory control contended however that: "Production does not start with the removal of the main stem from the middle of the leaf tobacco, but with the aging of the tobacco leaves. Storage is much more in the tobacco industry than storage in the ordinary sense. The tobacco acquires its taste during curing (aging) time. Overbuying means, then, merely the assumption of the "curing" function. This can also be done by the farmer, but this is a convenient method through which the tobacco company can exercise control over the costs of raw materials."

In line with this statement, it should be added that the cigarette industry works with relatively stable prices on packaged cigarettes. Prices tend to fall rather than rise, particularly if the government (federal, state, or local) puts an additional tax on cigarettes or on other tobacco products. To retain sales, the company might have to absorb the tax by keeping the price the same as before even though the tax is there. Thus, the company buyers go to auctions in the Carolinas, Georgia, Florida, and Maryland and into the Burley tobacco areas of Kentucky and Tennessee from mid-summer into mid-winter. If the price is too high, they abstain from buying or the auctioneer must come down if no one bids. Buying more when prices are low and less than enough when prices are high permits the tobacco company to attain a relatively uniform price over the years for its raw material. Therefore, it must be apparent that storage also fulfills the function of control over tobacco leaf prices.

The sales forecasting department supported the argument that their long-range forecast is instrumental in the attempt to control raw material prices and useful in the overall planning process by assuring the availability of raw tobacco. Since 1955, the statistical department has contended, the company has never run out of raw tobacco. Thus, it never had to go out and get some at premium prices. The long-range forecast has therefore accurately appraised the long-run demand and given important information to the raw tobacco buyers and indicated leaf tobacco needs over the long haul; thus, it exercised control over the monetary investment in leaf tobacco without taking a chance of running out of raw materials and getting into production difficulties.

Questions. Lack of profitability is a common industrial problem, but the causes of this state of affairs vary considerably. Thus, it is up to the student to determine in the case of the Cigarette Company, Ltd. the "real" factors which placed the company's growth in profitability at a standstill. Although the company made profits, it was not as profitable as most of the competing companies. Whether lack of profitability lies in the area of sales forecasting, production control, inventory control or in other areas is the question to which the student must find an answer.

1. List the various causes for the problem of lack of profitability as you see them.

2. State whether or not the sales forecasting department fulfills its function in so far as the production scheduling function is concerned.

3. Analyze the statements of the various production men, inventory control personnel, and sales forecasters to discover whether their opinions (statements) are valid.

4. Based on your analysis, state what if anything you find wrong with the company's sales forecasting method and with the information which it turns over to the production departments.

5. How could the sales forecasting, production, and inventory control men get together and make the best use of the services of the statistical (forecasting) department?

6. Do you agree or disagree with the various production experts that the nature of cigarette and pipe tobacco production is such as to require no sales forecasting to get utmost efficiency in production?

7. Do you or do you not consider the production man a bit old-fashioned in their attitude toward modern consumption as it is related to production?

8. If you were the president, what would you do to get the company back on its feet?

9. Appraise the CCL's managerial practices as a whole.

10-2. THE CHEMICAL SEALERS CORPORATION

Chemical Sealers Corporation, engaged in the production of plastic sealing materials, is located in an industrial city in West Virginia. The sealer material made by the company fills up seams and voids, thereby protecting metals from corrosive attack. The rubber-like sealer fluid can also be used for the vacuum-sealing of chambers, tubes, and other composite materials for the purpose of creating an airtight condition. Applied in liquid form, plastic sealers are air-cured in the sense that a liquid hardens when air-dried of its moisture content. Thereafter it forms an airtight and atmospheric-pressure-resistant seal.

The plant facilities consist of huge tanks and vats (see Fig. 1). The various chemicals are led into each tank by pipelines. The production process is invisible in the sense that the chemical contents of tanks are emptied by pumping the material out of the tank into barrels. Essentially, the material is prepared in seven different tanks and mixed in an eighth. When the components stand under certain pressure and other chemically favorable conditions, the chemical transformation is completed. Employees regulate production equipment by turning valves and adjusting valve settings in accordance with the readings of pressure, temperature, and other gages which measure gas formation and other processing symptoms inside the tanks. In the chemical sense, the sealer solution is created according to a patented formula by reacting organic dihalides (such as ethylene dichloride) with sodium polysulfide. As a result of the chemical process, a solid of high molecular weight is formed in the tank and this, in turn, has to be transformed into a liquid by a subsequent chemical treatment called reduction.

Specifically, the molecular structure of the liquid sealer material consists basically of a long chain of atoms, primarily carbon, hydrogen, and sulfur fused with oxygen atoms (that is, depending on the particular organic dihalide used). Since the raw material used to make sealers has varied, the process must be adjusted for the chemical characteristics of the material used as the reacting or reducing agent. Thus, employees must know how to read gages and adjust the control valves. Nevertheless, the production process is pretty much the same regardless of the chemicals used. Thus, once they learn the trade, the employees can work independently. While at times pigments must be added, this is not a part of the normal routine. Pigments are added only at specific customer request. In other words, even though production is for stock, at times special consumer desires are considered. In such cases, in the finishing stages, a batch equivalent to the customer's order is taken out of the otherwise evenly flowing production stream and specially prepared for the customer. Customers might require addition of carbon blacks to provide reinforcement or light-colored pigment to seal cracks where electrical wiring is isolated with the sealer material (that is, light pigments help to reduce electrical conductivity).

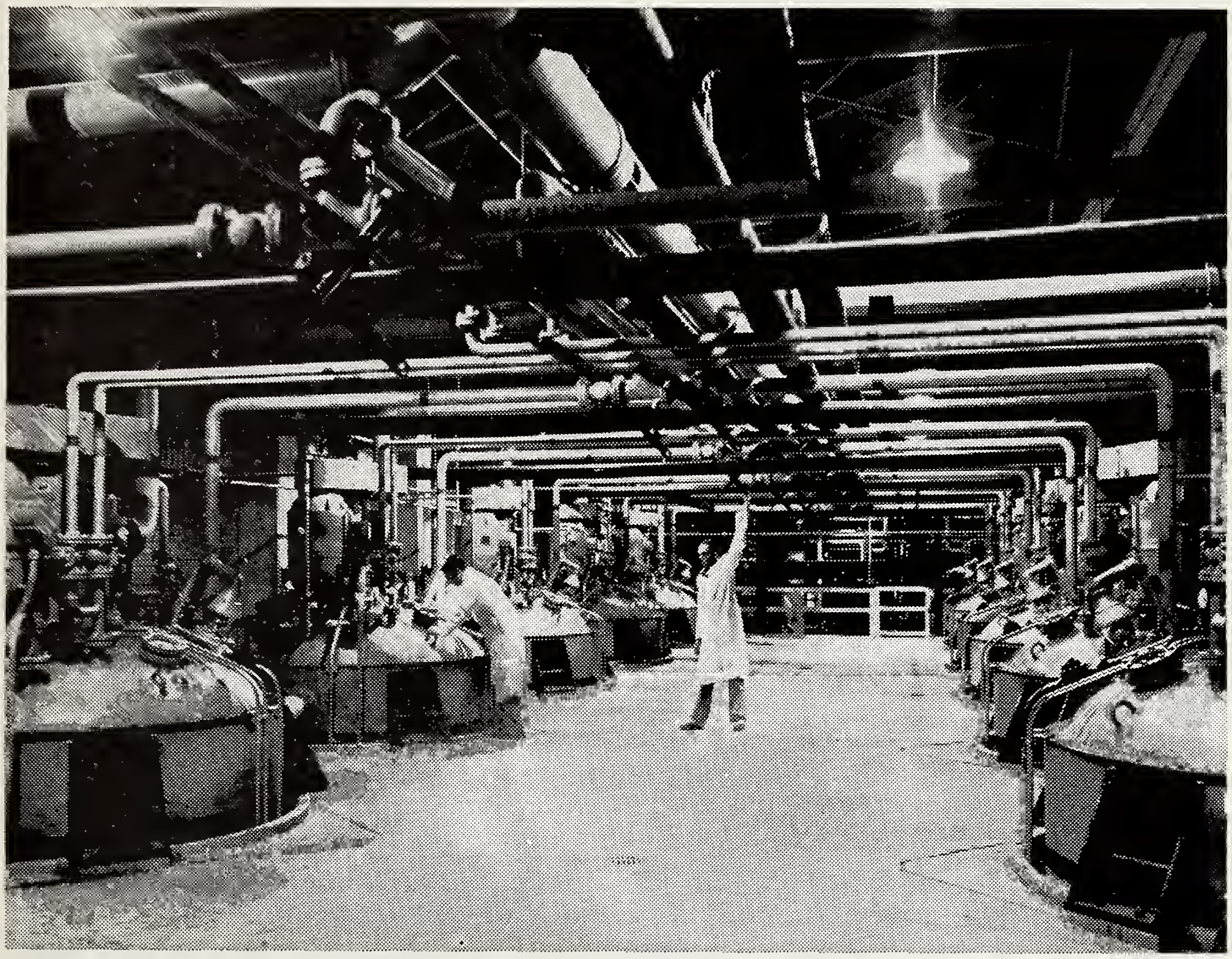


Fig. 1. Processing of synthetic rubber. (Courtesy of Firestone Tire and Rubber Co.)

Sealers produced by Chemical Sealers Corporation have many commercial uses, but they are usually of industrial rather than domestic application. The sealer, a mass product, is consumed in large volumes. It is conceivable, of course, that an ultimate consumer might purchase a small quantity to seal a leaking automobile window, leaking roof, or some other object, but as a rule large quantities are sold to aircraft, shipbuilding, construction, plumbing, and other companies. Vessel and ship builders are among the company's best customers; they use the material to seal wood decks and hull seams. The fact that the rubbery seal is capable of resisting weather conditions, oil, salt water, and many alkalies and that it remains flexible over a wide range of temperature fluctuations is a competitively great advantage of CSC products.

To explain the competitive advantage of the sealer and the reason for its being the leader in its field, it might also be worthwhile to know that the sealer compound's resistance to nonoxidizing acids either in moderate or low concentration is good. Even where mercaptan concentration is greater than 0.005%, the plastic sealer is still quite useful. Thus, the sealer's usefulness in the aircraft industry is unsurpassed by any competitive product. Here the sealer material is used for sealing pressure cabins, access doors, integral fuel and oil tanks, etc.

As apparent from above explanation, Chemical Sealers Corporation sells a superior product and probably for this reason commands approximately 50% of the total market. Even though the sealer is perishable, it can be revitalized because of its solubility in ketone, esters, and aromatic and chlorinated hydrocarbon solvents. This is another advantage which makes it preferable to other similar products. Capturing such a large segment of the industrial market is an apparent result of long years of successful competition with other producers in the same field.

The company's sales records reveal a gradual but consistent increase in sales during the past 20 years. The company's growth appears, moreover, to be faster than the development of new markets or the growth of the industry as a whole.

One of the major steps in determining sales (and production) volumes is the study of the trend of industry sales. Because the company commands approximately one-half of the total market, it was reasonable to assume that the plant's output volume should be approximately one-half of national needs. For this reason, information is gathered about economic conditions which exist throughout the country and, particularly, in those industries which use the sealer material. The trade associations; governmental statistics on construction, shipbuilding, and aircraft contracts awarded; and private sources offer ample material on this subject.

The dollar value of the plastic sealer business has shown a steady increase of approximately $300,000 dollars per year. This figure represented in 1955 4% of total sales. Barring developments pointing to the contrary, Chemical Sealers Corporation begins with the assumption that this trend will continue in the future. If the company were to retain or boost its percentage sale of the overall market, it would have to increase its volume of output by at least 4% over the previous 12 months.

Prior to the determination of the yearly sales forecast, each of the seven divisional sales managers is asked to submit a list indicating the amount they expect to sell in their territory during the coming year. Their experience and first-hand knowledge of economic and competitive conditions is considered invaluable assistance in furnishing needed information. In turn, the sum total of this estimated sales figure is correlated and evaluated with the industry trends as previously indicated.

In order to determine the sales trend, the company's sales forecasting department compares yearly sales figures with those of past years and checks the development of sales as the months pass by. During the past three years, however, the trend of growth seems to have subsided (after reaching 50% of total industrial sales). The growth of industrial sales as such and the company's share of the market (which incidentally also increased steadily, edging up a few percent per year) combined has amounted to 7½% yearly. This consisted of 4% growth of the sealer business and 3½% growth of the share of the market in 1955.

In 1958, a recession year, growth fell from the 7½% in 1955 to 2½%; in 1959 (a recovery year) 3%; and in 1960, another recession year, −4%. The sales volume finally was 3% higher than in the previous year of 1960 as the end of 1961 rolled around. The latter represents an actual −1% fall in comparison with 1959.

Upon considerable amount of statistical research, the sales forecasting department has contended that the company's sales trend, as indicated by a series of yearly sales quantities, and the growth of the industry as a whole might have undergone structural changes. This conclusion was reached after a substantial loss the company suffered in 1958 and again in 1960. Owing to lack of knowledge and experience with less than the normal growth, the sales forecasters overestimated the market both in 1958 and in 1960; then goofed again in 1959 and 1961, when they underestimated the market. Based on the rush orders and overtime work, the company could have sold more than it actually did. Since sales were lost, the figures used for the sales forecasting procedure were now somewhat out of line, because actual sales were not necessarily representative of potential sales (that is, sales which would have been made, had the company had enough sealer material to ship to the customers). The net result of these errors was a substantial reduction of company earnings in recovery years and actual losses in bad years.

Let us now retrace a bit to see what happened back in those years beginning with 1958. As revealed by Fig. 2, as a result of erroneous forecasting, the company's output in both 1958 and 1960 far exceeded consumer demand. Although these goods were sold in the following year, the sealer

Year	Yearly Output (drums)	Dollar Value of Sales	Dollar Value Due to Growth	% Share of Markt.	% Share Change	Loss in $	Industry Sales in Dollar Value of Business 1948/1961
1948	540,000	5,389,500	300,000	39½	0	----------	13,644,303
1949	585,000	5,918,000	300,500	40	½	----------	14,799,500
1950	620,000	6,190,000	310,000	40	0	----------	15,475,000
1951	650,000	6,597,500	290,500	41½	1½	----------	15,897,590
1952	680,000	6,834,453	300,000	42	½	----------	16,272,507
1953	700,000	7,010,500	234,500	42	0	----------	16,691,666
1954	750,000	7,409,500	290,500	43½	1½	----------	17,033,333
1955	887,000	7,847,500	300,000*	47	3½	----------	16,606,808
1956	800,000	7,928,500	350,000	48	1	----------	16,517,708
1957	800,000	8,206,250	325,000	49	1	----------	16,747,448
1958	880,000	8,328,125	203,125**	50	1	307,000	16,656,250
1959	800,000	8,577,968	249,843***	42	–8	----------	20,423,733
1960	850,000	8,234,850	–343,118**	50	8	474,000	16,469,700
1961	800,000	8,152,502	–82,348**	40	–10	----------	20,381,255
1962	850,000	?	?	?	?	?	

*indicate information mentioned in the case

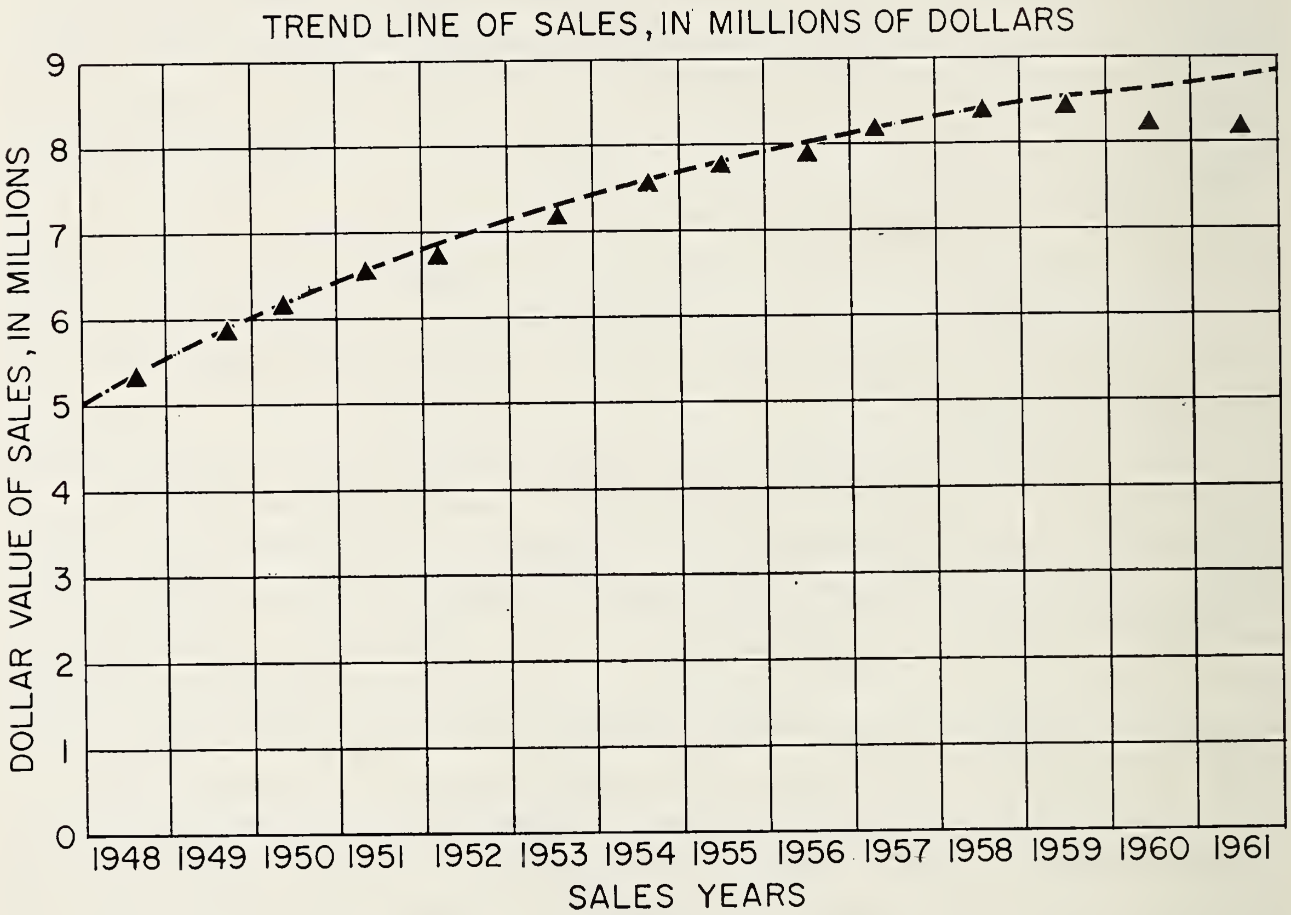


FIG. 2

material was somewhat stale and customer complaints and rebate requests cut seriously into profits. To top all of this, the production departments produced (because of faulty sales forecasting for the years 1959 and 1961) far less than the actual demand. The loss in 1958 amounted to $307,000 and in 1960 to $474,000. Profits in 1959 and in 1961, despite the tax-loss carry-overs, fell from $7 per share in 1957 to $1.72 in 1959 and $2.50 in 1961.

The above experience has emphasized to Chemical Sealers Corporation the importance of accurate sales forecasting as the foundation of good scheduling and associated profitability. Owing to the high degree of perishability of the sealer material (that is, substantial loss in moisture content), it was necessary to see to it that the production volume equaled actual sales in any given month, quarter, or production period. In view of its industrial rather than domestic (household) sales characteristics, it was impossible to raise the sales volume by an advertising campaign.

Since these losses were sustained and the earnings drastically reduced, the sales forecasting division was instructed to focus considerable attention on general economic conditions; particularly to the general economic climate influencing total industrial demand. The impact of the national economy gained considerable strength as soon as the company's total share of the market approached the 50% mark. Furthermore, the forecasting division was also instructed to pay more attention to seasonal variations in demand; since even minor fluctuations can precipitate financial losses. Since the plastic sealer hardens during an extended storage time, the sealer material becomes more difficult to handle. In other words, when the material does not flow smoothly, it takes twice or thrice the time to fill a void. Although it can be liquefied by mixing with ketone, ester, or chlorinated-hydrocarbon solvents, the process takes a great deal of time and effort on the part of the user.

Because in recent years stale merchandise (from a period of surplus production) was often sold, customer dissatisfaction was quite prevalent. While in most cases it was merely expressed, many customers actually demanded a rebate from 5% to 10% indicating that they did not want to pay full price for a shop-worn product. It was claimed that, because of the use of stale sealing material, the labor cost on jobs rose.

Furthermore, because of the longer storage, capital was tied up longer than it otherwise would have been. Also, the big inventories raised storage costs substantially because the plastic sealer material had to be stored in air-conditioned storage rooms.

Since the sales volume used to be predictable, the company could operate continuously in spite of a fluctuating demand during the year. During the summer months demand was higher than during the winter season. Because the company had a guaranteed annual wage provision in its labor contract, it was essential to operate continuously. Excessive layoffs could have caused a serious financial burden. The seasonal fluctuations were eliminated by the production of some, but not much, sealing material to stock. Barring exceptional circumstances, the company's policy was to produce at the rate warranted by demand. If in one week only 38 hours were worked because of lower demand, in the following week or in any other subsequent week not to exceed 6 months, production could be extended without overtime pay (that is, the 2 hours could be carried over for 6 months). It was of course in the interest of the company to schedule operations as evenly as possible.

The sales forecast applied to one year, but after each month had passed, the thirteenth month always became the twelfth in the sales forecast. This rolling forecast permitted a continuous sales prediction. The sales prediction was adjusted after each month when the future became a bit more crystalized. Everything was tentative until the last day of every previous month.

Questions. The student's basic task is to discover in this case whether the losses the Chemical Sealers Corporation has suffered and the low earnings plaguing the company can be attributed to the sales forecasting procedure. If wrong conclusions were drawn and caused overproduction or underproduction, it is apparent that suggestions of how the errors can be avoided in the future can remedy the situation. Of course the student must base his opinion on the knowledge of the correct methods of sales forecasting. Hence, prior to analysis of the problem, it is advisable to have a good idea of how the forecast should be made.

1. Which of the two approaches discussed in this chapter is used by the Chemical Sealers Corporation to forecast its sales and production? That is, does the company start with the general and conclude with the specific or build up a forecast from the specific geographical sales predictions to the overall production program?
2. List the steps which the company has taken in order to form a sales conclusion.
3. Criticize the information gathered by the Chemical Sealers Corporation. Is it adequate to make a valid forecast of future sales?
4. Check one by one the various comparisons the company made and comment on the resultant "correlation" the company claimed has existed.
5. Check the assumed sales trend to determine whether on that basis the output was correct.
6. Determine the ease or difficulty existing in this industry to predict potential sales and make provisions for the production of the right quantity at the right time.
7. If you were to make a sales forecast, how would you go about predicting the company's sales? a) Do you agree in general with CSC's procedure? b) What would you do differently? c) Would you make a sales forecast at all?
8. Is the Chemical Sealers Corporation's sales forecast correct from the point of view of statistics?

10-3. THE OUTBOARD MOTORS CORPORATION

The main plant of the Outboard Motors Corporation is located in Chicago, Illinois. Both parts manufacturing and most of the assembly work are done in this plant.

The company's six product lines are widely distributed throughout the United States. Although quite similar to one another, the company considers only two motor models as being sufficiently standardized to warrant making all component parts for stock and warehousing a certain number of assembled motors for future sales.

Although the company makes a sales forecast, it is used as the basis of production only in the above-mentioned two product lines. The other four product lines are scheduled for production on a "call" basis, that is, as dealer orders call for them. Nevertheless, six items are heavily sold in the summer months of May, June, July and August; they are stocked, in March and April, however. During the winter months, only December is a good month, when outboard motors tend to be given as Christmas presents.

OMC's annual forecast, made in December, is used mainly for production scheduling. To avoid the possibility of serious errors, it is revised in every quarter. Although the usefulness of the sales forecast is beyond doubt, only the $160 and the $200 models are produced and stocked on the basis of the sales prediction. Nevertheless, the forecast is a great help in the planning of the production of all other models. Models have changed every year, but model changes are hardly more than camouflage and represent merely changes in appearance rather than changes in basic construction.

Despite careful attempts to keep up a year-round production, assembly authorizations—with the exception of the previously mentioned two product lines—have been irregular because of the highly volatile market demand. This was aggravated by the fact that minimum lead times for most parts varied from 3 to 6 months. Indeed, because of long lead time it was not unusual that a dealer canceled his order even before the assembly of the parts into an outboard motor could begin. The main reason for cancelation was, of course, that customers were not willing to wait much longer than a few weeks for the execution of their orders. Although these motors were not entirely different from the $160 and $200 motors, they had to be custom-built according to the customer's specifications.

The company was engaged primarily in assembly work. It purchased a large majority of the parts used in these motors, except the "unique" parts. These were made or built in the company's own machine shop or wiring assembly. The basics, that is, the parts basic to all or most models, were ordered from suppliers on a repetitive basis. At the beginning of a forecast year, an "open-end contract" was given to the suppliers based on the probable need as indicated by the sales forecast; release schedules were sent to suppliers as soon as quarterly adjustments were taken care of. As a result of "too much hesitation" on the part of management to produce ahead of time, except in the case of two product lines, the company often lost business which it could have had if the company had been prepared to make a rapid delivery. Inability to make nearly immediate shipments was seriously affecting the company's share of the outboard motor market. Nevertheless, the company enjoyed a good reputation in the outboard motor field because of the reliability of the motors and because OMC's fine workmanship in general placed a quality product on the market. By the same token, when the company fully succeeded in meeting demand in all product lines, this was usually done through overtime work or a great deal of subcontracting the assembly of individual subassemblies. Despite overtime work and pay, however, when demand was harnessed, profits were high enough to cover the additional expenses. Thus, the company considered this "luxury" worthwhile under the circumstances. The reasoning was that a loss in sales would have otherwise meant an irretrievable loss in profits.

Whatever forecasting the company had was done by three independent approaches which were finally correlated with one another:

1. Field Forecast. Dealers and salesmen made an estimate of sales (broken down into different models) for the coming year. Dealers were also asked to estimate the dollar value of expected sales. As an aid, they were furnished with a mimeographed sheet indicating both dollar value and quantities sold in their territories during the previous 5 years. These returns were tallied by each divisional sales manager, who also made additional changes in the estimates in light of the then prevailing economic conditions. Finally, all divisional sales predictions were forwarded to the field sales manager who again "doctored" these figures to attain an even greater degree of accuracy.

2. Product Manager's Forecast. There were two vice-presidents in the home office charged with the responsibility for deciding on the various product lines under their respective jurisdictions. Accordingly, these field forecasts were funneled through them. After their approval, that is, after a further revision, the volume to be produced in each quarter was determined. These were then broken down into both style and price range.

3. Sales Forecaster's Report. The company retained on a consulting basis an economist whose main task was to adjust the forecasts whenever, on the basis of his knowledge of economic trends as expressed in selected economic indices, he thought necessary. Among the many factors, the following were carefully checked on the ground that they seemed to be factors influencing outboard motor sales:

a. The net national product (which roughly corresponds to the national income) and the disposable income. Of the latter, 10% is estimated to be the figure, which on the average, will be allocated by families to recreation. This portion of the income is then classified into groups of given age brackets beginning with the 20-year-olds.

b. The length of work week for the nation as a whole.

c. Information collected from travel bureaus and chambers of commerce to determine how people spent their vacations in past years. The data were so tabulated as to reveal the increase or decrease of the number of vacationers spending their vacations near coastal or lake areas.

d. Forecast of companion products such as boats, water skis, sporting goods, and fishing equipment.

4. The sales forecaster's report was further refined by constant checking and rechecking of factors that would ordinarily affect the breakdown of the current 1-year forecast and predetermined quarterly periods. Thus, for instance, the Outboard Motors Corporation had recourse to surveys conducted by various associations to confirm the forecast's accuracy. In line with such attempts to verify sales predictions, opinion surveys were made at various boat shows throughout the country during winter and early spring. Furthermore, seasonal weather forecasts were carefully studied to confirm the sales predictions for given geographical segments under the tacit assumption that adverse weather conditions might cut down on demand in particular geographical areas, which could substantially reduce overall demand. The forecast of companion products was also checked during the year by carefully studying department store sales volumes, wholesaler and manufacturer reports, etc.

Localized changes, in any of the above, were important to correct possible errors and to thereby avoid the necessity for drastic schedule changes in midstream. They were also used to change forecast sales and to contribute to the accuracy of the forecasting procedure, that is, to prevent either over- or underproduction. If sales were to lag behind predictions, assembly operations could be halted during certain months, but the production of *basics* could still continue since they could be used in the following year's model run. The costs of storage must, however, be always taken into consideration.

In the middle of each quarter, the forecast for the remainder of the year is revised on the basis of the recommendations of the two vice-presidents in charge of the two different product groups. While the recommendations are always discussed with all other interested groups, the two vice-presidents' opinions (decisions) are considered final. The opinion of the field organization is requested primarily for the second-quarter review, just prior to the heavy sales and shipping season.

It must be apparent that field forecasts are based primarily on individual "feel" of the market (competitive activity, future buying plans of principal population segments, past sales volumes, etc.), even though a serious effort has been made to guide the preparation of local field forecasts. The company believes that a good sales group's detailed knowledge of customers' future needs can be effectively harnessed by making it easy for them to prepare a meaningful estimate of future sales.

The product managers' (vice-presidents') approach was similarly largely one of judgment. Since their primary information comes from the sales field or is based on incoming order trends compared with those of previous periods, information about current use of products competitive with boats, or current advertising efforts of competitors, they tend to reflect hunches rather than facts. Nevertheless, in the final analysis these are seasoned judgments.

The sales forecaster's approach is somewhat more statistical. Because a large portion of demand for the company's motors originates from disposable income, coupled with leisure time, sales prediction is largely a matter of translating the disposable income and leisure time into sales terms. The correlation between company volume and income is, however, by no means a precise one. Apparently, "income versus sales" can be affected by other forces such as unusually large amounts of forward buying, changes in the proportion of replacement buying, and competitive growth about which the company has only fragmentary information. Consequently, the statistical estimates must always be altered in light of all other relevant factors. For these reasons, the Outboard Motors Corporation time and time again has undertaken various experiments to determine the relevancy of given data in order to confirm existing relationships or show the need for some additional facts deemed to become a new parameter.

Since no reliable data on industry sales volume are available, there is no real check on the underlying factors causing certain inconsistencies between industry and company sales volume. Although attempts have been made to determine the size of the total outboard motor market and the share OMC holds, the results of such surveys served merely as the basis of a historical comparison rather than as a guide to future outboard motor sales.

For short-term checks either on the statistical estimates, field sales, or product lines predictions, the sales forecaster maintains data on incoming orders for the six product lines. These are charted as 12-month moving totals and placed on a chart located in the production control office (which is adjacent to the statistical department). The production control department is responsible for scheduling the arrival of parts based on the suppliers' lead times; the parts the company makes in its Chicago plant are turned over to the producing departments in form of shop orders. However, all these purchase orders (releases) and shop orders are based—to some extent anyway—on the sales forecast figure. The forecast is tentative, however, until the quarterly revision is taken care of. As soon as the forecast is adjusted, the production forecast is approved and the production control department makes its decisions relative to production schedules (both releases to vendors and shop orders to producing departments).

Since the company has found it difficult, with present forecasting methods, to predict the market and base production on the forecast, officials of OMC considered the need for a drastic overhaul of the whole sales forecasting procedure. The decision was precipitated by the fact that, despite a rising sales volume in all product lines, OMC's total profits increased only by 2½%. Probably most manufacturers would be happy about an overall increase of 2½% in profits, but OMC is not satisfied because, in the opinion of management, a larger sales volume should justify a correspondingly larger profit. The fact that other motor manufacturers fared much better than the OMC is a serious indictment of current practices and shows that something is not quite right with the company's production system.

At the request of the president, the production department (headed by a vice-president) submitted a report indicating the present method used to translate the sales forecast into production schedules. The president maintained that a proper use of the sales forecast in manufacturing is one of the major opportunities still available for cost reduction. The president is hopeful that if the error is found—no matter whether it lies in the forecasting procedure itself or in the translating of the forecast into production schedules—layoff costs and overhead in general can be reduced to negligible levels. As it is, one of the major cost elements is connected with excessive hiring in one period and excessive layoffs in another period. The president further contends that plant capacity utilization can be increased, which could effect a rise in profits in addition to improving operator performance (based on a 3% improvement factor indicated by the company's learning curve).

According to the report, the following method was used to convert sales figures into production schedules:

The forecast is broken down into product mix. The latter is derived from approximations based on past percentages. Since each outboard motor contains many parts which are common to all motors, each item on the bill of materials is listed on a 6 × 4 card. Each of the six product lines has a different color code (white, blue, yellow, pink, green, and brown). Thus, the company has now six packs of cards on which all parts used in every outboard motor are listed by name, part number, and model—the color, however, indicates the model. Based on a recent sales forecast, the yearly volume is roughly divided into:

	A	20,000
	B	34,000
	C	50,000
	D	23,000
$200 model	E	100,000
$160 model	F	281,000

The expected yearly sales are multiplied with the number of parts (common or special part) making up that product. This gives the predicted yearly need for the parts in question.

When the total need for all parts is known, the cards are separated according to part numbers. Since the same part (regardless of which outboard motor it is a component of) always carries the same number, the card, regardless of its color, is pulled out and classified into piles each representing a common part. The total of all of these parts is then the predicted yearly demand for the part in question.

Since each and every outboard motor has, for example, a tank cap, part

No. A-7723, the total quantity of tank caps during the year is 508,000, plus 50,000 (10%) to compensate for the reject factor. Surplus tank caps, if 10% are not rejected, are used for the replacement market.

The total quantity required is charted on a bar chart called the inventory control chart. The release schedules are based on this chart. A chart kept on the wall is maintained by production control clerks. Every time shipment is made, an appropriate adjustment is made on the chart.

The inventory control chart represents the availability and reorder points for various parts. The production schedules (item by item) are computed merely by comparing forecast sales figures with the available plant capacity, which is of course known. The capacity of the assembly section is expressed in number of motors which can be produced per day. Each model is assembled in the same manner and the same assembly workers are involved. Assemblers are shifted at times from work station to work station in order to keep the production line moving. Where a bottleneck seems to develop, manpower is added. Although the method of assembly is similar irrespective of the model, the capacity of the assembly line varies somewhat from model to model. It takes, for instance, somewhat longer to assemble model E than model F. It takes 1½ times as many man-hours of labor to assemble 100 outboard motors of model A than model E. Calculations are based on a company load chart projecting the 6 months sales ahead of time. The chart is adjusted each month with the changing market situation. In the past three years, however, the charts have been revised every month, because production schedules have had to be stepped up. This has created a great deal of work, second-shift problems, subcontract worries etc., on the one hand, and layoff problems when demand subsided, on the other hand.

The sales forecast is used mainly to determine the utilization of available plant capacity. The company load chart is divided into assembly work loads and into major departmental work centers. Within each department the foreman does his own scheduling. The whole production program is charted for the coming 6 months, and when one month has passed, another month's production program is added.

Questions. The student should approach the case of the Outboard Motors Corporation in the manner explained in the instruction for case studies. Thus, the following questions should be posed:

1. What are the *symptoms* indicating that the company's sales forecasting does not accomplish what it purports to accomplish? (In order to discover the symptoms, the student should be clear in his mind about the results a company can reasonably expect from a sales forecast.)

2. Why does the OMC's sales forecasting procedure not accomplish its purpose? (That is, what *causes* precipitate the inaccuracy in the sales forecast?)

3. Suggest improvements of OMC's sales forecasting.

4. What real use does the company make of sales forecasting?

5. Criticize the field forecast.

6. Criticize the product manager's forecast.

7. Comment on the method of the sales forecaster.

8. Do you agree with the method used to dovetail the three forecasting components?

9. What use is made of the sales forecast by the production department?

10. To what extent, if at all, does company profitability depend on the sales forecast at OMC?

11. If you agree with the sales forecasting method but object to the production planning method, or if you disagree with both, state the nature of your disagreement.

12. Draw up some sort of a chart which reveals in a concise form the system the company uses to translate the sales forecast into production plans.

13. What, if anything, do you find wrong with the logic behind the whole sales forecasting procedure (or with the use to which it is put) in the production control procedure?

14. If you were called upon to be an advisor (consultant) to the company, what suggestions would you make on the basis of what you learned from the description of this company's forecasting procedure and interpretation of the results for production purposes?

15. Do you agree with the company's current practice of using the sales forecasting data mainly for the $160 and $200 models or would you have an idea of how to make use of the data ascertained by the forecasting procedure for the production of all six product lines?

16. Try to make a comparison with the description of the sales forecasting method in the automobile industry (page 419) and the Outboard Motors Corporation case to see whether that kind of forecasting is applicable here. If so, what must be done differently to adapt the same forecasting and production control system?

17. To what extent do you find the outboard motor business (as described in this case) different from the other sporting goods fields?

18. In the final analysis, what, in your opinion is a) wrong with OMC's forecasting method, b) faulty as far as the production planning method is concerned? c) Comment, if applicable, on the lack of relationship in this company between inventory and stock control of parts and finished units and the production control department on the one hand and the production control department and sales forecasting as it is related to parts and components manufacturing, on the other hand.

chapter 11

Production Planning in Intermittent Job Shops

THE JOB SHOP PROBLEM

Presupposing an understanding of job shop operations from Chapters 6 and 7, the basic characteristics of consumer demand will be singled out to explain the raison d'être of intermittent production. Consumer desires for goods of industry differ. In the large majority of instances, the consuming public is not satisfied with "uniform" mass products but wants to have special features built into the products. Since the consumer—whether an individual, institution, or business unit—wants diversity and is willing to pay for it, the less efficient intermittent production is warranted.

The job shop problem, however, lies not in the differences which the manufacturer must build into the goods, but primarily in the limited *size* of orders. Unless the order is large enough to warrant the high-cost equipment, the value of the equipment cannot be depreciated. It should be understood that high-speed mass-production machinery pays for itself because, by the time the production run is completed, the equipment which was used to turn out a large number of units is just about worn out. The fact that the intermittent job shop produces specialty items in limited quantities—in quantities not large enough to depreciate the value of its equipment on any single production run—will explain the principal reason why *general-purpose machinery* is used. By converting machinery to various production duties, a sufficient mileage is gotten out of the machines to recover the capital investment.

Only by creating large production volumes artificially—i.e., by using the same equipment again and again on different orders—can the equipment pay for itself. During the process of sustained use, the value of plant facilities will be reclaimed bit by bit, since the price of each unit of output will contain roughly the monetary equivalent of the wear and tear on the equipment. Theoretically, when the machines are ready for the scrap heap, an adequate amount of money has been set aside in the form of depreciation to replace the worn-out facilities.

Accordingly, job shops must build such plants and use such machines as are convertible to different purposes. The use and reuse of the same equipment for different orders will ultimately, despite the small size of most customer orders, permit recovery of the value of the equipment. In connection with the use and reuse of the same machines, however, a considerable amount of planning work is involved, because the apportionment of machine time among different uses must follow certain preplanned patterns. Delivery commitments, costs, and other factors must always be kept in mind in setting up these plans for equipment utilization (scheduling). This work of apportioning the available machine capacities among different uses constitutes the job shop problem.

A typical job shop (pure job shop) would not start production until it received an order. This does not preclude, however, some degree of preliminary planning associated with the solicitation of orders. Although a considerable amount of time might be spent on the preparation of a bid, this work might turn out to be a complete waste. Since bidding is competitive, it is possible that the contract will be awarded to a competitor who happened to set his price and delivery date more in line with the customer's interest.

A pure job shop—and admittedly there are few pure job shops—does not produce stock items. Thus, the pure job shop depends on constant inflow of customer orders. Nevertheless, no one should assume that intermittent production is a feast and famine type of business. There is usually enough business going around to keep most "efficient" job shops busy. Barring a serious recession, a healthy job shop has several months of order backlog. Because order quantities are customarily small (from a few to a few hundreds), one should not conclude that job shops are necessarily small plants. As a matter of fact, job shops can be considerably bigger in some instances than some mass producers.

To sum up, the main characteristic of the intermittent job shop is its ability to accept orders with different specifications. Since it tends to utilize the same equipment for a multiplicity of orders, the job shop problem centers around the development of diverse routings which tend to compete with one another for time on common machine facilities.

SOLICITATION OF PRODUCTION ORDERS

As far as this book is concerned, bidding and the process of estimating associated with it are important because they tend to result in orders. The consummation of an order will set the whole network of planning forces in motion. Furthermore, bidding as such also interests us because it involves planning efforts closely resembling the process engineering and the production control functions. In other words, if a company had made a careful estimation, the preliminary work referred to in Chapters 6 and 7 as process and methods planning would be shortened at the time of a firm order. The reason for this is obvious. If process sheets, bills of materials, and other relevant plans were already prepared for the purpose of estimating, only improvements would have to be made on them. Production could then start soon after an order was received, because much of the planning work had already been done.

Because of the uncertainty surrounding bidding and contracting, many companies try to develop simplified methods of bidding. In other words, they avoid the bulk of the planning work as much as possible. Care must be exercised, however, in order to prevent making far-reaching errors in estimation. A miscalculation of either the bid price or the delivery date, or of both, might have serious financial consequences.

The solicitation of contracts begins with the receipt of the customer's design drawings. Before the company receives such drawings, they must have responded to an invitation to bid on a prospective order. Contrary to continuous production, where the manufacturer designs his own product (keeping customer desires always in mind), the intermittent job shop ordinarily does no designing. The customer, through the design drawings, sets his product specifications and wants to know at what price and delivery date the vendor could produce the item in question. Price and delivery date are specified in the bid.

ESTIMATING

How many orders a company will obtain depends largely on its ability to make realistic bids. It is difficult, however, to make an accurate estimate of operating costs and delivery dates far in advance of performance. The only thing available for the estimator is the design drawings (it could also be a chemical formula) containing certain production specifications in addition to the structural characteristics of the product.

Estimating will also determine, to some extent, the profitability of an order. An underestimation of operating costs might cause losses rather than profits to the company to whom the contract is awarded. This tends to be so because the lowest bidder has the greatest chance to get the order.

In view of the difficult nature of bidding, many different experts are involved. Contrary to beliefs about the role the production control department plays in bidding, that department actually has little to do with estimating per se. During the production process, of course, production control can influence both the costs of production and the delivery of the goods in question. Although the production control department assists in the estimating process, its main contribution is the development of preliminary production schedules and determination of the earliest possible delivery date.

COST ESTIMATION

Preliminary to bidding is the estimation of the labor costs. The assumption is that, in the labor cost, clues can be found to the magnitude of the overhead charges. Thus, probably the most important aspect of the whole estimating procedure is the determination of the labor costs. The estimation of material costs is relatively simple because the prospective vendors of raw materials will usually give reliable information about the possible costs. With raw material costs out of the way, the emphasis will be placed on the estimation of the labor costs.

Estimating is a cooperative undertaking in the sense that many departments are involved. Occasionally, the production control department is charged with the task of pulling together the necessary information to establish both production costs and delivery dates. Once these are ascertained, cost and delivery estimates become goals as well as forecasts.

It sometimes happens that a company will unwittingly underestimate its contract price, and then when the contract is awarded, it will seem impossible to make the goods at the contract price. To avoid losses, the industrial engineering group and all the production experts will try to develop production plans such that the goods can be delivered at the bid price. This might mean serious shortcuts in many areas. While in most instances better methods than those that were considered during the estimating procedure can lead to lower costs, shortcuts might also reduce product quality. To avoid such an eventuality, many customers, particularly the United States government, are willing to sign cost-plus contracts. Thus, a company which underestimated its operating expenses will still have a chance to recover the cost expended in excess of the estimate. Even though there is a ceiling on profits, there is no risk involved, and the company is not forced to make qualitative shortcuts at the expense of the buyer.

Since bidding is a competitive affair, most companies are forced to set their bid prices as low as they dare to. That mistakes are possible goes without saying. However, some competitors purposely bid under the predicted costs of production to take a contract which will keep the shop busy during a seasonal valley or business recession or in the hope that the first contract will be followed up with several repeat orders. As long as the company can cover its out-of-pocket costs and, possibly, some percentage of the overhead charges, it might be worthwhile to operate at a loss rather than shut down. This might be particularly true when a business recession starts toward the end of a company's fiscal year during which the company made a sizable profit in the first two or three quarters. In that case, previous profits (that is, that part of profits which would go toward taxes) will be used to cover the difference between costs and revenues and the contract might tide the company over a short-lived recession.

Since the competitors' bid price is unknown, it might be apparent that a great deal of conjecture is involved in industrial bidding and estimating. The previously mentioned reasons for underbidding are, obviously, not necessarily mistakes, but wise business decisions. If the plant can operate without layoffs, it is possible to capture some savings in form of lower unemployment insurance rates, more uniform production per man-hour of labor, or even a greater output per unit of time attributable to the learning curve which might take effect—a concept according to which experience on the job over an extended period of time tends to increase employee skill and productivity. Furthermore, if the fear of unemployment is eliminated, there is no need for employees to stretch the job.

TECHNIQUES OF ESTIMATING

As already implied, there are basically two methods of estimating: 1) careful estimating and 2) approximating. No details on careful estimating will be given because it closely resembles the planning work already discussed in great detail in Chapters 6 and 7. Careful estimating takes a considerable amount of time and effort, but, of course, it results in a fairly accurate cost estimate. Approximating, in turn, will greatly accelerate the process of estimating, but it might not be sufficiently accurate to allow profit on the contract. The fact that, out of every ten bids, a company might obtain only three or four contracts speaks strongly for bidding on the basis of approximations rather than for careful estimates. The possibility that the planning work might be fully wasted and the fact that even the careful estimate is seldom foolproof contribute to the general acceptance of approximation as a technique of estimating.

Approximation might be based on the idea of "standard costs." In some companies the similar nature of incoming orders warrants the use of standard costs, because they can successfully appraise the costs which will likely occur. In pure job shops, however, standard costing is not a likely method because the similarity between orders is too small to permit the use of standard cost data. A company engaged in repetitive production might employ standard costing with greater confidence than the pure job shop engaged in the making of nonrecurring specialty items.

Because there is often some degree of "work" similarity, which does not necessarily mean structural resemblance of two or more products, costs can still be approximated merely on the basis of past cost records kept by the cost accounting department. To do so, the experienced estimator must be able to recall two or more jobs made in the past and appraise the possible costs which a new order might entail. In a foundry, for instance, this might be quite simple. The shape castings take might be quite different, yet as long as the cubic content of one mold is the same as that of another, the chances are that the cost of making the casting will remain the same. The cost of making castings of similar weight—cubic content and weight are proportional—might require the same amount of pouring time and raw material. Hence, the costs of making castings of different sizes will be a matter of past records. The same can be true in many job shops where there is a common denominator for cost formation.

Since a careful estimation relies on bills of material, process sheets, tool-up considerations, etc., once the route has been developed, each operation must be translated into operating costs. The type of labor at each operation can be ascertained by the type of machine and the tolerance requirements; in turn, the type of labor will readily reveal the wage rate for that kind of occupation. Evidently, the nature of wage payment might also reveal something about pending costs. Merit ratings, wage incentives, or piece rates will result in predictably higher output per unit of time. Thus, the rate might be higher, but the cost per unit somewhat lower. The determination of the labor costs is the crucial element in estimating, because the other cost elements can be either derived from the estimated labor costs (ratio between direct and indirect labor, ratio between labor costs and overhead, etc.,) or ascertained from vendors on the basis of the predicted purchase quantities and scrap factors.

THE COST BREAKDOWN IN ESTIMATING

Reference is made here to careful estimating rather than to approximating. Therefore, the estimator must first of all know the operations involved in the production of the various piece parts, subassemblies, and major assemblies, including the time required for their execution. Finally, the class of labor necessary to perform the operations in question must be known.

The indirect costs (overhead or burden) cannot be ascertained as easily as the direct labor costs, because it is impossible to determine the exact amount of wear and tear on the machine, the exact value of heat, light, fire insurance, managerial services etc., chargeable to each operation and the contract as a whole. Although one knows that indirect as opposed to direct costs tend to be greater, there is no precise formula capable of helping in the appraisal. However, there are in use several methods which roughly approximate the relation between labor costs and overhead expenses.

The most common method is the historical appraisal of the ratio between labor costs and overhead expenses. The assumption that a machine requires the services of an operator leads to the conclusion that a certain ratio exists between labor and overhead costs. While this becomes less and less true in the process industries and in companies where automation enters the picture, in the pure job shop it is still a valid assumption. Over a period of time, records might indicate that a constant ratio exists between the size of the labor costs and the overhead expenses. Thus, if the total labor costs during the year were $100,000, whereas the total fixed costs amounted to $200,000 —and this ratio has been pretty much the same during the past few years —the assumption can reasonably be made that the ratio is 1:2. Therefore, for every $1 of labor cost the estimator charges $2 for overhead. While this is not a precise measurement, it can be justified on grounds of past experiences. Of course, this ratio could be anywhere from 1:2 to 1:6 or more. At any rate, this measurement can be used for the purpose of cost estimation and bidding.

In careful estimation, where each individual operation is subject to analysis, it might be necessary to calculate the actual machine cost by determining the actual mileage gotten out of that specific machine on each operation (contract). This is a rather complicated procedure because the actual use must be compared with either the acquisition or the replacement costs of individual machines.

When the indirect costs have been appraised, the direct costs (labor and material) plus the indirect costs will determine the costs of production, and a given profit margin will make up the bid price. Everything being equal, the lowest bidder tends to receive the order.

As is apparent from this description, a great deal of time and effort are required in the appraisal of the costs and bid price. If the bidding was unsuccessful, it is also apparent that the costs involved in bidding went down the drain. This is the reason why companies try to design simplified methods of estimating. Although some time must always be spent on estimating, one tries to spend on this work an absolute minimum of time without risking errors. If the contract is obtained, it is evident that all costs involved in estimating will be recovered.

Estimating the Delivery Date

The bid is for both delivery date and price. The determination of the former can follow pretty much the same pattern as cost estimating. The careful estimating of delivery dates is extremely time consuming. For this reason, an approximation method is used when feasible. By the approximation method the company merely appraises overall departmental or plant loads (in multiplant companies) in terms of man-hours of labor to see whether enough capacity is open to handle the order. Actual assignments would, of course, be handicapped if several work orders had to be assigned to the same department or machine to get contracts out in time. In contrast to this is the careful delivery estimate which resembles the scheduling procedure to be explained in this chapter in great detail. Thus, further explanation is postponed.

THE INVISIBILITY OF PRODUCTION FLOW

In commercial aviation, flight schedules are visible only on paper, because the routes based on altitudes and directions are bound to be invisible, and in intermittent production too the flow of production is invisible. In a sense, there is a production flow in job shops, but it cannot be visually followed up in the same manner as the production flow of a TV set. The production flow of jobs shops can be depicted only on charts and schedules, that is, only on paper. Of course, everything moves slowly but surely from the receiving department and stockroom toward the shipping room; but the product is often stored for weeks. Nevertheless, despite temporary storage times or delays, there is a definite flow. Of course, each order and each part thereof takes a different path in the shop. This is obvious, since each piece part (component) is made differently and the route each item (component) is to take will largely depend on the sequence of operations and on various design specifications. Evidently, the job shop planner is really concerned not with the contract as a whole but always with each part thereof. Each piece part or component constitutes a separate production problem.

Since the order as a whole will be executed only if each of its segments has been carried out, the planner of an order must solve as many problems as there are parts and operations involved in the order. The job shop planner with 100 orders (consisting of 10 parts and 10 operations to be performed on each part) on its books will have to solve approximately 10,000 problems (100 orders × 10 parts × 10 operations), and with every addition of a new order some new conflict between the orders might develop. This is so because each piece part of an order follows its own unique path. It is important that every operation (and each order might represent dozens of operations) be fitted perfectly into an already existing overall program to the point of blending into it.

Although the scheduling problem might be explained later, at this point it should be pointed out that all delivery dates on each contract (and on each individual operation thereof) must always jibe with all previous routing plans.

From the point of view of path planning, one is concerned with 1) the nature of the operations to be performed, 2) the kind of machine on which the operations must be performed, and 3) the time and sequence. Once all three are properly determined, the necessary time, in a specified part of a day, week, or month, on the type of machine capable of performing the operation in question must be found. If machine time is not available on a specific calendar date, the operation must be shifted to a later or earlier period. But if it is shifted ahead, it is imperative that some other operations also be pushed ahead. None of the dependent operations can be arbitrarily shifted. If the drill press which is supposed to tap the hole is not available, a forward shifting of tapping requires that the immediately preceding operation be equally shifted. In other words, operation sequences cannot be neglected. In this kind of planning work most decisions are arrived at simultaneously with several other related decisions. In order to dovetail operations and schedules with one another, the planner must correlate every operation with every dependent operation until finally all schedules and routings are perfectly synchronized. Of course, the next production order (i.e., the individual operations thereof) might create a series of new problems and necessitate a certain number of readjustments.

Routing and scheduling are flow plans, but they are only on paper. In contrast, the flow on a production line is quite different; it is a built-in flow.

There, barring machine breakdowns, nothing can interfere with an orderly flow. In job shops, since everything is only on paper, many things can happen to prevent the execution of operations. Just as it is simple to win a basketball game on paper but difficult to do so on the gym floor, so it is easier to plan the flow of job shop operations on paper than make it a reality. Nevertheless, the plan must be there before orderly movement of materials is at all possible. Before an order is closed out, plans might be changed dozen of times. But, since everything is on paper only, sudden changes in routing can easily be accommodated. This would not be quite as easy in continuous production, because there the plant layout as a whole would have to be changed.

The production flow is invisible because so many cross movements take place that the product's back-and-forth movement could not possibly be visually followed up in the production shop. A map of the plant on which the routings would be indicated could not be used because if there were many lines showing back-and-forth, zig-zagging, and repetitive movements, it would be impossible to recognize the path of production. Particularly if the route of an item were to be also tied to time schedules, difficulty would develop in illustrating product flows through the shop. The charts discussed in Chapter 9, however, particularly in connection with intermittent production, enable such presentation. Thus, a flow of production can be created, by means of a machine load chart, by meaningfully arranging equipment capacities among different uses. The planner can plan on completing the order as a whole at once, but he can also plan the order's completion in economic lots. The alternatives are many! If the processing time from the first operation to the last must be speeded up, it is possible to take advantage of overlap scheduling on different machines as illustrated in Fig 11-1. However, this is possible if the standard time on operation 1 is less than on 2 and that on 2 is less than on 3. If the reverse is the case, speedup is not possible and gapped scheduling must likely be practiced.

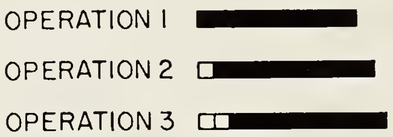


Fig. 11-1. Overlapping schedules.

TECHNICAL PLANNING

As soon as a contract is awarded, the planning work begins. As already indicated, if the company made a careful estimate in order to place a bid, the work yet to be done is more or less an improvement over that which was already done during the estimating procedure. It must be apparent that a careful estimate already took into consideration the processes on the various parts which go into the product, including the possible production requirements. Now the final design of tools (jigs, fixtures, and gages) must be decided upon; the process sheets, the various specifications, the bills of materials, the possible codings of the various processing information, etc. must be taken care of. The various methods engineering groups might now contemplate better ways of making the product than originally anticipated. Before the plans are finalized, it is conceivable that the plans which were used to prepare the bid will have been discarded because better ways have been found to make the goods in question.

THE ROUTING FUNCTION

The routing function is a derivative of process engineering. As a matter of fact, in many companies no distinction is made between routing and process engineering. Generally speaking, however, the two can be separated from one another. On the one hand, the technical problems might have to be solved by a high-paid process engineer; on the other hand, the clerical work involved in routing is carried out by a lower paid route clerk.

Since most of the information that is summarized and classified on route sheets has already been determined by technical experts, the question that arises is what is still left to be done. Specifically, processing instructions to start production must be simple and concise. The route sheet will therefore contain information necessary for production in a concise form. Mind you, the information would be written somewhere, but someone, say, the router, must summarize it on a single sheet of paper. The paramount value of the route sheet, then, is that the parts of the "jig-saw puzzle" are placed in proper relationship to one another.

By writing out a route sheet, the production control department not only coordinates the efforts of several interrelated departments (by taking the information they developed and harmonizing them into a route sheet), but also makes certain calculations which implement the overall production plan. Thus:

1. Comparisons are made between cost factors so that machine assignments can be made in accordance with the best-cost choice for the original as well as the alternative machine.
2. The output volume is calculated in such a manner that the reject factors are given proper allowance.
3. Determination of the most economical production run is made if the order as a whole cannot be processed at once.
4. Codification of production papers is accomplished.

Furthermore, the route sheet is so developed that scheduling is facilitated. Thus, information such as time study data, setup time, tool number, and material specifications is written on the route sheet, and this will facilitate the scheduling function. Evidently, the schedule requires knowledge of performance times and setup requirements, which will be based on information the route sheet contains.

Provided a process sheet is available, routing is not complicated but merely time consuming. It involves a tedious accumulation and arrangement of a large array of diverse information which can be located in different departments of an industrial enterprise. Among many other data, the route sheet will list the name and identification number of the order and the part in question, and also its subassemblies if it is an assembly process. Evidently, each part has its own route sheet. Furthermore, the route sheet will contain the number of pieces the order calls for, but complemented with the overage which must be added to compensate for the rejects. If the item must be produced in lots, the number of units in the lot must also be listed. Ordinarily, however, the question of economic lot size is no problem in pure intermittent job shops. In the repetitive type of production (see next chapter) it is, however, of great importance.

In order to make up a route sheet, the router must, of necessity, rely on the help of a series of other departments. The best method of processing comes from the process and industrial engineering departments in form of a processing authorization. In repetitive production, the authorizations might be written on mimeographed master route sheets. More will be said about these in the next chapter. Actually, the information is merely copied over, but since additional information must be appended, the route clerk makes the necessary computation as he goes along. Often, the route clerk checks the various blueprints and copies some hidden but necessary information on the route sheet. It is true that the foremen could do this too, but it is the beauty of the matter that, in well-run shops, the foreman is no longer bothered with the checking of petty details. His task consists mainly of the supervision of men. The route sheet should be so prepared that a great deal of detailed planning on the part of the first line supervisor becomes unnecessary.

Codification the route sheet contains might be important because code numbers might make the task of various individuals concerned with production much easier. Since the route clerk has all the code books at his disposal, this is quite simple when it is done in the production control office.

Although no two identical parts should carry different part numbers, two different customers might have two different part numbers on their orders. It is often confusing as far as the producing departments are concerned to make two parts under two numbers. Therefore, during the routing process, one of the tasks of the route clerk is to check whether or not two different part numbers are given to identical parts or to a piece part which is essentially the same as a previous part, except that an added bend, such as by the last operation, makes it different. By standardizing the part names and numbers, it will be possible to process many parts together and run them through the shop as one order. It is evidently much cheaper to make one setup and run out two parts (even though they have two different order numbers and be made for two different customers) as if there no difference were between them. Special identification must, of course be designed in order to avoid confusion at the time the two parts must be separated for production as well as cost accounting purposes.

The route sheet should also indicate setup times in order to facilitate scheduling. In most job shops, however, setup times are not collected carefully enough and are based merely on educated guesses. Since route clerks should not be given discretionary power to make independent decisions as far as production matters are concerned, it is advisable to classify setup times according to the type of jig, fixture, etc. Thus, a certain type of jig might be given 15, 30, 50, or 60 minutes of setup allowance. If setup allowances are kept in a setup book, the router need merely pick the appropriate setup time out of the book and indicate it on the route sheet. Along with the setup time, the tool number can also be listed on the route sheet, provided the tool is used on several jobs. This will facilitate capacity calculations on the one hand and later identify the tools to be used by setup men on the other.

While the process sheet specifies the type of machine to which each operation must be assigned, it usually does not state which of a series of identical machines should do the particular job. Thus, the route clerk must make this additional recommendation, basing it on current availability of capacity on that machine and on the costs incurred with that equipment. Each machine has some attribute which makes it more suitable for one particular operation assignment than another; it might be ease of setup, better feeds and speeds, greater or lower costs of acquisition, greater accuracy, or greater output per unit of time. An antiquated machine would conceivably be adequate for an order of a few pieces; a more modern high-speed machine might be more suitable for a larger order. Of course, the router's discretion is confined to relatively minor decisions, because the process sheet tends to set narrow limits within which the router can make such choices. If the router cannot find an 80-ton press as specified, he might split the operation to two punchings which might be performed on two 40-ton presses in sequence.

If so far the impression was created that routing consists of nothing more than gathering and implementing already available information, our task was fully accomplished. Indeed, routing is a routine activity, provided a process sheet is available. Most decisions made by various individuals in the divergent departments of an industrial enterprise are simple decisions. Nevertheless, overall production efficiency depends on these detailed decisions to a greater extent than on the overall plans laid down by higher echelons of management. The reason is that unless the big decisions are implemented and detailed at lower echelons in piecemeal, the big decisions cannot possibly be successful. Obviously, the big decisions are just as important, but no one should consider the small decisions insignificant. In the aggregate, these little decisions make an industrial organization function efficiently.

ECONOMIC LOTS IN PURE JOB SHOPS

When the order calls for a few pieces, economic lot quantity does not really mean anything. But when the order must, for some reason or other, be executed in installments, it becomes essential to determine the proper size of each lot. The reason for lot production may be that the completion of the order as a whole and at once would tie up a busy machine much too long for comfort. Therefore, the company tries to put several different items through the same machine in rapid succession. At any rate the question is, what should be the size of the lot?

Because the next chapter devotes some space to the question of economic lot quantities, at this point only mention is made of the fact that an economic lot is always that quantity causing minimum costs per unit of output, including storage costs, carrying charges (interest payments on working capital), and wages paid for material handling.

DETERMINATION OF THE PRODUCTION QUANTITY

That an order calls for 500 completed units does not imply that only 500 units must be started with. Rather, a great deal more must be put into the stream of production to end up with just 500 units. The reason is that some goods in process will be rejected, and extra units roughly the size of the expected fallout rate must be started at the very first work station. One of the tasks of the router is to determine the size of the "extras," above and beyond the order quantity.

It should be remarked that faulty pieces are not necessarily caused by human errors. It is possible that the raw material is not sufficiently homogeneous, and a hard spot in a piece of metal might, for instance, cause tool breakages. A drill bit broken in a half-drilled hole usually causes a rejection because the broken drill bit cannot be retrieved from the workpiece. Often the machines are imperfect or the tools wear out faster than expected. At any rate, management must estimate the probability of rejects and produce a sufficient number of units more than the order calls for to make sure that the plant is never short by a few pieces.

This "overage" has in the past been based on professional guesses. Either the foremen knew from past experiences how many more pieces should be made or the engineers estimated the overage to be produced. Nowadays, tables might be developed on the basis of careful probability calculations, in which case the reject rate is plotted on charts. The router then does not have to make guesses, but merely has recourse to these tables. The same thing would be true in chemical, cement, or paper companies or in oil refineries, where customer orders must be met. Surplus liquids are produced on the ground that shrinkage is the rule rather than the exception (due to evaporation, leakage, and condensation) and can be precalculated on the basis of past experiences.

Barring reliance on professional guesses, it appears advisable to develop such tables to make it possible to arrive at rather accurate reject factor rates. Assuming that the product in question consists of 10 component parts, each going through 10 different operations, it is apparent that the reject rate must be computed on a cumulative basis for each part. If past experience indicates a reject rate of 1% in each operation, on the part as a whole the reject rate will be approximately 10% (that is, 10 × 1% on each operation).

Despite the value of reject factor rate tables, many companies shy away from developing them, partly because of the expense but primarily because most production men believe that they can guess just as well as probability can calculate. That is, in order to set up reject factor rates, a sufficient number of past examples must be accumulated to make the calculations. Since machines, and people, tend to make the same mistakes over and over again, it is possible to arrive at quite reliable reject rate factors. When the table is determined, it can be used by the router to determine the number of extra pieces or extra quantities which must be started at the very first work station.

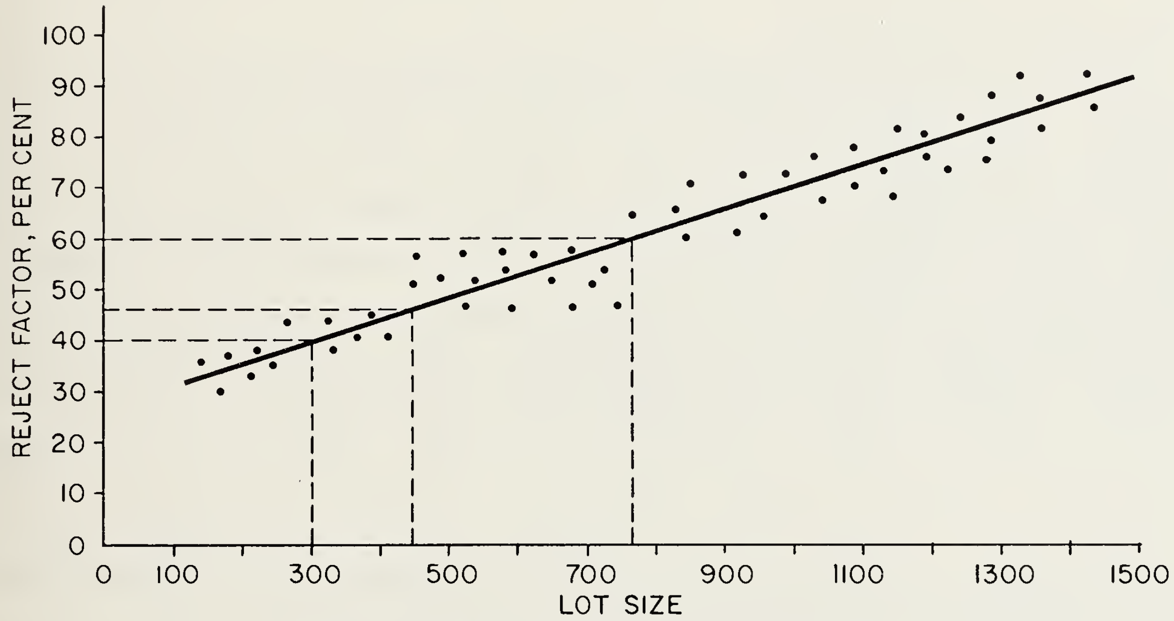


FIG. 11-2. Theory-of-probability chart.

To establish a reject rate curve, customary reject rates per unit must be calculated (probability values). The horizontal line should represent the lot sizes scale and the vertical scale the reject factor going from 0 to 100 per cent. The curve we get may have to be smoothed out. But once such a curve is established, it is possible to make intelligent decisions without making any guesses. Obviously, the reject factor will still represent a good guess, but this is a probability value rather than guess. At any rate, it is likely that better estimates can be made with the use of charts based on the theory of probability than with the customary commonsense judgment (see Fig. 11-2). What does Fig. 11-2 indicate? It says that for a lot of 300 units, 40% additional pieces (120 pieces) must be started at the first work station in order to end up with

300 acceptable workpieces; for a lot of 450, 45%; and for a lot of 780, 60%. This chart is exaggerated, but if the chart were based on probability values, it would represent the fallout rate for which allowances must be made.

The extraordinary importance of using a simple predetermined table or chart for reject rate determination should not be underestimated, because the table speeds up the decision-making process and makes a routine decision out of a serious decision. It not only helps in setting the quantity for scheduling purposes, but also helps in cost estimating. It would evidently be unrealistic to calculate the labor costs on the basis of the order quantity, because a great deal of labor time also goes into those pieces which are ultimately rejected. Thus, in cost estimation the labor time and material values rejects contain represent the same kind of costs (including overhead charges) as the salable units, except that the cost of rejects cannot be recovered.

Workplace Assignment

One of the most important activities performed by the router is the determination of the specific machine which should perform a specific operation. Although process sheets indicate the machine to be used, no process sheet specifies to which one of the many available machines of the same kind the work should be assigned. Yet, from the point of view of operating costs the specific machine might be of great importance. If we assume the availability of 10 identical machines which were acquired at different times at different prices, "younger" machines are more modern than some of the older ones which operate at slower speeds, can attain less accuracy, and take more time for setup. Since the cost and output with any one of these 10 machines will vary, it is important to always pick the most suitable machine for the job in question. Thus, the router must find not only a machine capable of performing the work, but also the one capable of performing it at the lowest cost.

The router must pick the best machine under the circumstances. Although the lowest combination of labor, setup, overhead, and material costs must result from operating the machine, the operation must still be completed sufficiently ahead of time to meet delivery requirements. This might mean the assignment of the worst machine to a few-piece order and the best or the second-best machine to the long-run orders. If the machine of first choice has already been legitimately assigned to another important job, the second-best machine must be selected.

In the past, the above problem had not been scientifically answered. Since the advent of operations research, it is not unusual to employ linear programming methods to establish the proper production program in which the various cost elements find due consideration (see Chapter 15).

SCHEDULING

Sequentially next in production control is scheduling: establishing starting and finishing dates for productive actions. This, particularly in intermittent job shops, can be quite complicated. The fact of the matter is that a limited amount of production equipment—that is, the time available on the equipment—must be apportioned among a large number of orders with regard to the intricate interrelationships between operations in terms of 1) time sequences and 2) costs which will be incurred. It is important to ascertain that starting and finishing dates are always in accordance with all other important considerations.

From Chapter 9 it seems apparent that scheduling resembles train movements, where starting and arrival times are of extraordinary importance. Train connections are intimately related to all other train movements over a given roadbed. While the main-liner might govern the movements of the lesser trains, it is itself influenced by the latter. While this analogy seems to be applicable to continuous production rather than to job shop scheduling, the fact is that freight movements are scheduled irregularly over the same roadbed. The freight movement should be considered the *new order,* and it must be correlated with the already scheduled main-line movements so that no interruption, delay, or collision will result. In job shops it is not freight trains, but new orders that come in as old orders are closed out. The schedule of every new order must be integrated with the processing of goods already in partial stages of completion. Care must be taken to prevent conflicts in the use of machinery, since any given machine can handle only one job at a time. Yet equipment time must always be so allocated that everything is done in appropriate time and at the lowest costs of production (which implies *without* overtime work, if possible).

CENTRALIZATION VERSUS DECENTRALIZATION

Centralization of scheduling work means that every job assignment comes from the production control department. Decentralized scheduling in turn would mean that the scheduling is done by the various departmental foremen or their superintendent. While these two methods might be equally useful, under certain circumstances one can be more effective than the other. Generally speaking, centralized scheduling is better in large companies where the complexity of interrelated operations is so great that only a central production control department can keep track of all interrelated operations and make coordinated decisions in respect to them. While the departmental foremen cannot see beyond their own departments, the production control department sees everything from a single perspective.

In many companies, particularly in repetitive operations, a combination of centralized and decentralized scheduling might be most economical. It should not be forgotten that production control work in itself is expensive. Thus, if 100% control is not necessary, the production scheduling work can be divided between the departmental foremen and the production control department. More will be said about block control and load control in the next chapter, but at this point mention might be made of the fact that in such situations departmental work loads or work assignments to key machines might be made from the central production control department. Within the department, however, and as long as overall production schedules are maintained, it is up to the foreman how he allocates the work loads among the different machines. In other words all jobs must be finished within the centrally allocated time.

Although decentralized scheduling is still prevalent throughout American industry, the main point this book tries to drive home is that centralized scheduling can be beneficial in many more situations than currently assumed possible. The reason for this might be that many companies do not know the benefits of effective production control work; hence, they are not aware of the fact that centralized production scheduling would cut plant operating costs considerably more than the cost of maintaining a production control department. Obviously, the production control department might consist of one man or it might occupy a score of production control experts: routers, schedulers, expeditors, and dispatchers. As long as even one production control man can be kept busy on a full-time basis, a centralized production control might be very beneficial. Of course, a great deal depends on the nature of production.

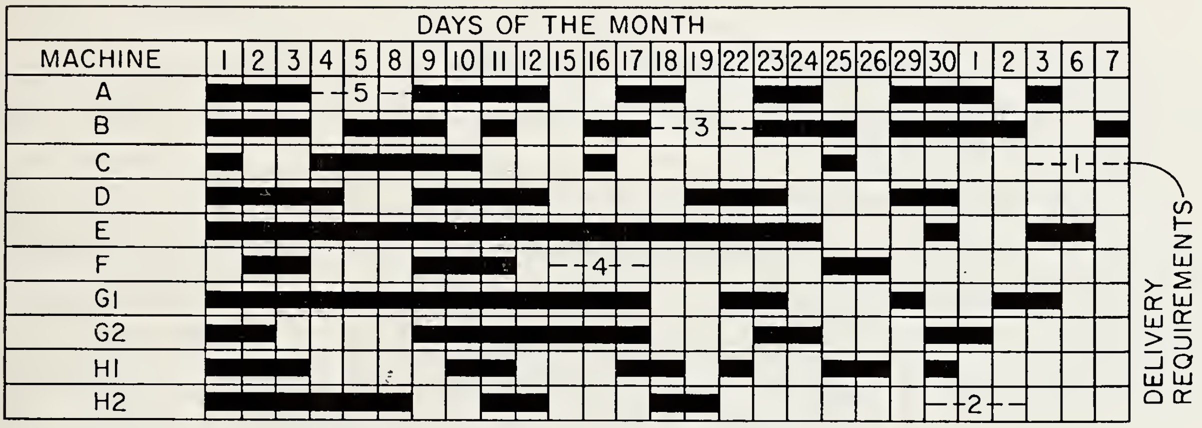
It has often been said that centralized scheduling becomes too rigid to suit the purposes of many companies; this is particularly true in companies where rush orders and emergencies are the rule rather than the exception. Despite opinions to the contrary, the scheduling function can be accomplished with perfect satisfaction by a central production control department. This requires, of course, a perfect communication system between the shop and the production control office. It is essential, therefore, to develop a paper work system whereby the office knows—within a reasonable period of time—what has transpired in the shop: machine breakdowns, order cancellations, reschedules, delays because of employee illness, inability of an inexperienced employee to meet production standards. Also, before a centralized production control department can operate, it is essential to have predetermined *time standards* necessary to the making of production schedules. If time standards are not available, decentralized scheduling is the only feasible method of scheduling. In that case, the foreman is the best man to judge how long a given job should take and to manipulate the available equipment time in his department so that the best mileage is obtained from men and machines. But, when all prerequisites are present, centralized scheduling can be highly effective.

SCHEDULING PROCEDURE

Shop loading is similar to establishing class schedules by students. The student finally arrives at a predetermined schedule of what he will do from Monday through Friday from 9 to 10, 10 to 11, etc. The various scheduled classes are listed on a sheet of paper. Production schedule is no different from such an allocation of time—that is, apportionment of machines, departments, and assembly lines among different duties. A chronological list indicates what is being assigned to a given machine, department, and production line.

Once the routing function has been taken care of, it is the function of scheduling to find time on specified machines so that given deadlines can be met. The deadline is largely determined by the various interrelated operations, but mainly by the delivery commitment which tends to govern the whole scheduling procedure.

Working back from the delivery commitment, the scheduler books the utilization of the needed equipment so that each part or component is completed when the item is needed by the customer, a subassembly or assembly station, or by any other related department. Let us assume that a job shop has a few machines and the same equipment is used to produce all sorts of customer orders. Evidently, to accomplish all work which must be completed on any given equipment requires the apportionment of equipment time so that each customer's order is accomplished in the right time. By setting up a simple chart capable of indicating the available equipment in the manner shown in Fig. 11-3, it is possible to make reasonable commitments and also be reasonably sure that the schedule which is set up will be accomplished.



Schedule backwards; last operation first ←

FIG. 11-3

From time study data sheets the standard hourly output can be developed. If we have an order calling for 1440 pieces (rejects are disregarded for the sake of simplicity) and the required machines are available so that delivery can be made in accordance with customer shipment specifications, then we merely try to fit the order (the operations of an order) into the schedule. Since it is possible to meet production standards provided there is excellent supervision or a piece rate or wage incentive system, there is no reason to doubt that time standards will indeed be met. Now, if each of the 1440 pieces must go through five operations—on machines A, F, B, H, C in that order—the chart permits the scheduling of operations so that the job will be completed on the seventh of the next month, assumed to be the customer's delivery requirement.

If realistic time study data are available, we always know what employees can produce. Let us assume for further simplicity that each operation takes the same amount of time, although this would obviously never be the case because each operation at each work station would have its own time standard. But, if we work with this assumption, the bar chart in Fig. 11-3 will indicate the schedule excellently. On the chart machines are listed vertically and the days of the months horizontally. If the time standard for every one of the five operations which the part must go through is assumed to be 1 minute per piece (60 units per hour), the production of 1440 pieces will take 3 days at every work station. Since the job must be completed on the seventh of the following month (see the last column in Fig. 11-3), the scheduling procedure starts *backward* from the seventh of the next month. This is done because we do not want to be finished faster than necessary—the customer might cancel the order; any merchandise stored for too long might be damaged; and working capital might be tied down in idle inventory too long; etc. By starting with the delivery date and the last operation, not with the first one, we readily know when we should start to be ready when needed. Of course, if we wanted to be sure, we might want to finish the work a day or two earlier. In that case we would adjust the schedule accordingly.

According to the schedule, the last operation on machine C should begin on the third of the next month and be finished on the seventh. The operation before the last one must start on machine H on the thirtieth, the preceding one on machine B on the eighteenth and be completed on the twenty-second, the second operation on machine F on the fifteenth and finished on the seventeenth. Unless we want to break the production lot, the first operation would start on the fourth and be finished on the eighth. Thus, to complete the appropriate set of workpieces, the schedule indicates the starting time on the fourth of the month and the finishing date on the seventh of the next month.

This kind of scheduling is excellent, but as stated before, it depends upon two things: 1) availability of time study data and 2) a wage incentive system of either the piece rate or the bonus variety. Unless we know how long an operation takes and unless we are reasonably sure that the required production quantities (output units) in the shop will be produced, scheduling is bound to be a hit-and-miss proposition. And if accomplishment is important, overtime work might be necessary in order to get the job out of each department (or machine) in sufficient time to send it through the next department (or machine). Actually, the letters A, B, C, D, etc. could have represented departments instead of machines. In the connotation we have used, the chart was a machine load chart; if the horizontal line represented departmental work loads, the chart would be a departmental work load chart (see Chapter 9 for a review).

This example indicates, among other things, that scheduling cannot be done in a vacuum, because old orders cannot be disregarded and because, in order to assure their accomplishment, time standards must be fostered by well-designed wage incentive systems and to begin with, be available to the scheduler. If management is reasonably sure that everything will go according to schedule, new orders can be accepted until all the open spots on the chart not reserved for any waiting job are filled. If more orders were accepted than the plant could currently handle, they could be accepted only with faraway delivery commitments and be backlogged. When business is good, most job shops quote a long delivery date, but the backlogging of orders is done on a first-come, first-served basis. Figure 11-3 also indicates the idle capacity; thus, if rush-rush work is requested at the last minute, management knows whether it can accept it or must refuse it. Of course, if one of the machines breaks down, until repair is made, the jobs waiting for that machine will be held up. In such an eventuality, orders must be rescheduled, or when the machine is in operation again, overtime work must be put on the critical equipment. Once back on schedule as set up, operations are bound to be orderly again.

To be realistic, one should be guided by the fact that schedules are changed quite frequently. As a matter of fact, the schedule at the end of the month seldom resembles the original schedule as it appeared at the beginning of the month. Does this mean that one should not schedule at all? Certainly not! At least until the schedule went sour, the plant operated in an orderly fashion; the goal was always known and everybody concerned with production was sure where he was going. After the schedule was changed, the new production plans gave new directions. Thus, the plant can tell sufficiently far ahead of time if troubles seem to develop, and solutions to the problems can be developed immediately.

Overlap Scheduling

If the schedule based on Fig. 11-3 had to be speeded up or if a rush order had to be accommodated by cutting into the time already allocated to another order, overlap scheduling could be tried to remedy the situation. In other words, the sequentially next operation could be started earlier or a bit later, yet timewise we would still be able to complete the order. In such a situation half or some other portion of the already completed workpieces accumulated during an earlier operation are transported to the sequentially next operation. Thus, for instance, operation 1 and operation 2 might be performed simultaneously. As a matter of fact, it is conceivable that while the tail end of a lot on operation 1 is being performed, operation 3 has already started on those workpieces which have already gone through operations 1 and 2.

Overlap scheduling then, means the transportation from one machine to the next of production of broken lots, as opposed to full lots and the performance of several operations concurrently. Overlap scheduling, when it is applicable, creates little, if any, difficulty, yet it has several advantages: 1) processing time can be shortened and 2) machinery can be utilized when it might otherwise have to stand idle. Therefore, overlap scheduling often permits getting better mileage out of equipment. A distinct disadvantage of overlap scheduling is, of course, the already mentioned added materials-handling costs.

According to Fig. 11-4, the overall processing time, as far as the order scheduled in Fig. 11-3 is concerned, cannot be shortened by overlap scheduling. Operations 4 and 5 can be speeded up, but operation 3 cannot possibly be speeded up because another operation stands in its way. Of course, if necessary, the scheduler should check on the operation blocking this contemplated arrangement to see whether or not it could be moved up or retarded a bit. If so, the schedules on two orders would be reshuffled to accommodate the need for overlapping. Operation 2 can be overlapped with operation 3, but again this would not do any good because operation 1 cannot be performed any earlier. It should be noted that in Fig. 11-3 the scheduling steps (counting backward) were given on the chart, while in Fig. 11-4 the operation numbers (sequence of operations) are given.

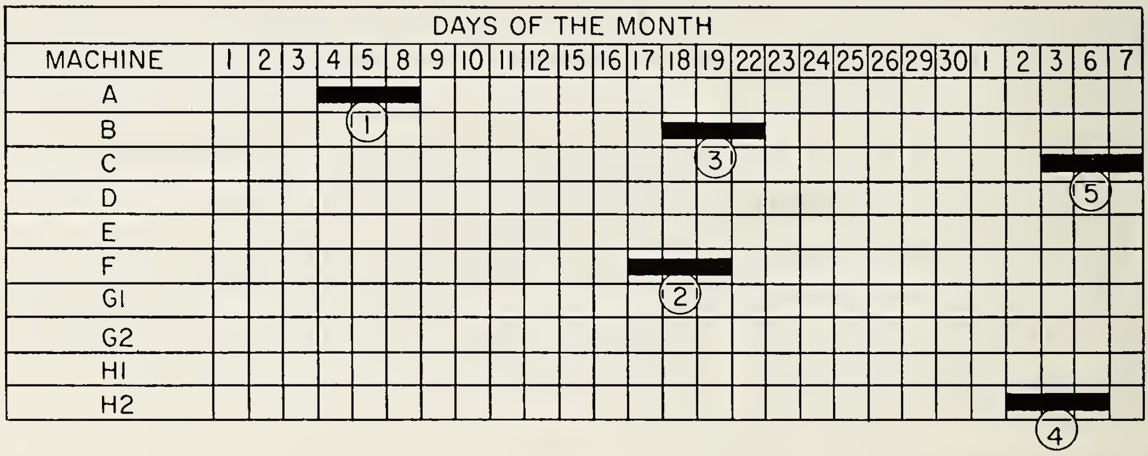


FIG. 11-4

SCHEDULING MULTISHIFT OPERATIONS

In order to illustrate multishift scheduling, the chart's calibration must merely be changed from days to man-hours of labor or to minutes. In other words, the time proportion which the chart represents must be maintained, but the horizontal lines will represent a correspondingly larger output capacity. Assuming that the monthly production capacity consists of 9600 minutes, it can be indicated for one-shift operation simply as 9600 minutes (20 working days × 480 daily minutes). Under the assumption that machines A and B are busy only every second week, this can be illustrated as in Fig. 11-5. To convert the machine load chart in Fig. 11-5 to a two-shift capacity chart, capacity is doubled on the chart by calibrating it differently. Thus we have Fig. 11-6. If the company wants to operate on a three-shift basis, the calibration of the scale will be adjusted correspondingly. Thus, it is entirely possible to make up machine load charts or departmental load charts to reflect one-, two-, and three-shift operations.

THE SCHEDULE AND THE PROGRESS CHART

Although the production program of a job shop can be charted on a progress chart, the latter has no meaning as far as scheduling is concerned. More will be said about a progress chart later; at this point we mention only that on it the overall production program of a job shop can be precisely depicted. But actually, the progress chart is meaningless because what the scheduler is interested in is not the overall picture, but something which indicates how the new order can be placed into an already crowded plant work load. This is, however, depicted on the previously described machine or departmental work load chart, not on the progress chart.

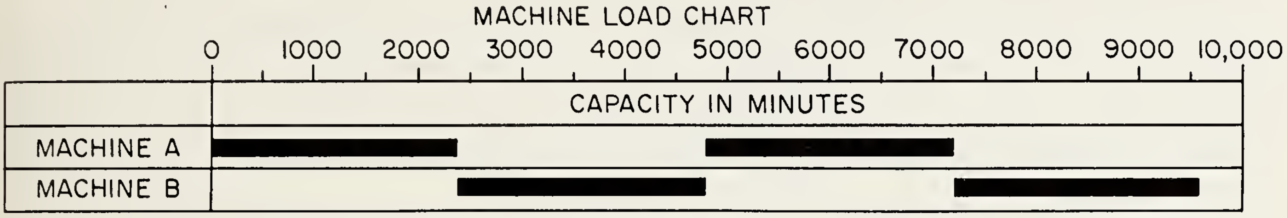


FIG. 11-5

SCHEDULING AND INVENTORY CONTROL IN JOB SHOPS

Barring situations in which the ingredients are the same and only the proportions vary or in which the raw material is always identical no matter how different the product's design specifications are, purchase requisitions are placed after the order is received. In other words, the pure job shop does not buy raw materials ahead of time and store them until use. The reason for not buying anything ahead is of course, that one never knows the customer's raw materials specifications.

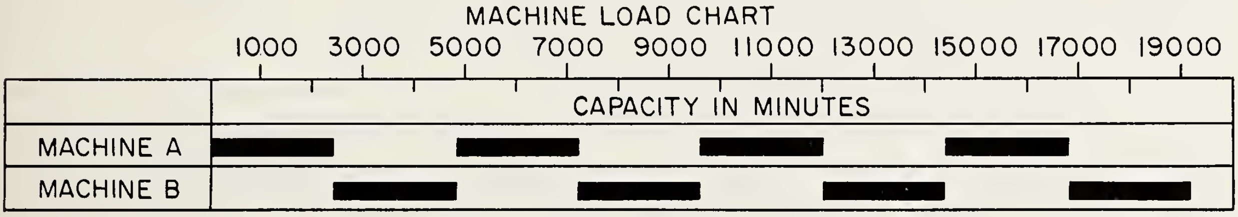


FIG. 11-6

Because the pure job shop seldom orders on the basis of the customary minimum-maximum basis, or for that matter, in any specific way, raw material procurement times must, of necessity, always be considered in the scheduling procedure. The schedule in Fig. 11-2 indicates that, in order to complete the order in question on the seventh of the month, the first operation must start on the fourth of the preceding month. Since the schedule so far has considered only the availability of machine time, it is evidently assumed that if capacity is available, the order can be executed. This is, however, an oversimplified view, because raw materials must also be ready prior to the start of the very first operation of the fourth of the month. It is apparent that the plant, before it makes a delivery commitment, must have a pretty good idea about raw material lead times. In the event raw materials cannot be procured sufficiently ahead of time to start the operation on the fourth, the schedule cannot be met and a new schedule must be set up.

It is essential that schedulers know the raw material supplier's lead time before thinking about production of the item at hand. Based on the schedule as established, the purchasing department will have as the procurement deadline the fourth or sooner (see Fig. 11-4). A serious delay in shipment of the raw materials will hold up production on the contract, and it is questionable whether a delayed arrival of raw materials will permit execution of the order by the seventh of the second month. In conclusion then, scheduling must know about the vendor's lead time before the production program can be finalized.

THE DISPATCHING FUNCTION

A representative of the production control department in the production shop is the dispatcher, who releases the production schedules to first-line supervisors. Occasionally dispatchers turn over the work assignments directly to workers. It should be apparent, however, that the latter method of dispatching can be very harmful if first-line supervisors are bypassed. Obviously, a worker who receives his work assignment from the dispatcher tends to feel that he is responsible to the dispatcher rather than to his foreman. Since the responsibility should be clearly indicated, the dispatcher should always work through the foreman.

Occasionally, dispatchers transmit production releases by remote control—teletype, telautograph, or by other means. Although this kind of dispatching can work, conditions in the shop might change too quickly to adapt to it fast enough to prevent development of bottlenecks. For this reason, dispatchers must always be in close personal contact with the shop.

The ways in which dispatching can be accomplished were mentioned merely to illustrate the fact that in different companies different dispatching methods might be employed. The correct method of dispatching is, of course, always the one which 1) strengthens, rather than weakens the foreman's authority, 2) is always there to help when needed, and 3) which can transmit reports to the central production control office without delay when things do not happen in accordance with routing, scheduling, and planning in general. Since emergencies, rush orders, and many other unforeseen problems tend to arise, there should always be someone down in the shop who can lessen a bit the rigidity of the schedules established in the ivory tower (that is, the production control department).

Mention was made of the fact that occasionally dispatchers are in direct contact with employees. A bit of explanation should be made at this point to clarify this idea of "direct contact." In repetitive-type production, rather than in pure job shops, production orders might be almost identical, but still minor variations must be kept track of and employees must be informed about them. As each employee performs his "routine," the nonroutine aspects of the job must be told him. For instance, a shirt manufacturer produces shirts of different sizes, sleeve lengths, colors, collar styles, etc. Since collars differ only in terms of size and style but the shirt is made in the same way, the differences must always be told to the men in the shop. The same is true in the manufacture of suits, shoes, and also many appliances such that some parts of an item will be different even though the appliance as a whole is pretty much the same. In such instances, the dispatcher's office directly informs the worker, by means of prepared forms, what changes must be made. Although the instruction is given directly to the worker, no one should assume that both the foreman and the dispatcher go *personally* to each employee and inform him what to do. The direct contact between dispatcher and employee usually takes place on forms coming *directly*, but not necessarily personally, from the dispatcher.

Let us not think, however, that dispatching is merely a mailman's job. In reality, dispatching involves a multiplicity of activities that have to do with turning over work authorizations to operating personnel prior to initiating production. Generally speaking, the dispatcher is instrumental in but not accountable for 1) creating an orderly flow of production, 2) providing the materials, tools, blueprints, transportation facilities, and any other factors, 3) supplying all information relevant to an orderly movement of materials through the stages of production when the job is ready to start, and 4) giving the "go-ahead" sign. Furthermore, the dispatcher is 5) the "guardian" of production papers (plans) until the date of production comes up.

The *filing* of production plans as a distinct dispatching function warrants further explanation. As guardian of predetermined production plans during the "waiting" period between the planning and activating of the contract, the dispatcher's office adjusts the plans as certain changes in production occur. Most of us tend to forget that a considerable amount of time gap, varying from a few days to several weeks or months or occasionally, as in the aircraft industry, to several years, exists between planning and execution. Thus, in some huge production programs, such as building bridges, skyscrapers, and dams, several years might pass between formulating production plans and making them a reality. As changes take place, it is the function of the dispatcher to adjust the plans affected. In other words, as the guardian of the production plans, dispatching is charged with constantly updating them.

It should also be remarked that dispatching *is* a clerical function. When the route sheet, along with blueprints, is turned over to dispatcher, a great deal of work remains to be done. The route sheet contains all relevant production information, including the production schedule; and as far as supervisory personnel are concerned it is *too* informative. Each departmental foreman is merely interested in the work assigned to his department. Therefore, before the various work assignments (operations) are distributed among the various foremen, the dispatcher's office breaks down the route sheet into *job cards* and *move cards*, in addition to preparing all sorts of production papers (tool orders, material orders, behind-schedule notices, and ahead-of-schedule notices). Thus, foremen receive the *production authorization* via the dispatcher's office seldom in form of a route sheet, but more often in form of job cards. The instruction package contains nothing but information relevant to the department in question, so that as little study of production papers as is necessary is required of supervisory personnel.

Considering everything, the main functions of dispatching can be summarized as follows:

1. Filing production schedules until date and time of execution.
2. Ascertaining physical availability of raw materials needed in production.
3. Making certain—prior to starting production—that tools, fixtures, and gages are available.
4. Seeing to it that machines are set up and ready to go at the time operations are scheduled to begin.
5. Preparing production papers, forms, blueprints, etc. needed by supervisory personnel in the administration of the production program.
6. Routing the internal traffic and materials handling to and from work stations as well as to and from storage.
7. Releasing work orders (operation to operation) in conformity with overall schedules and routes previously established.
8. Recording facts, unless other arrangements are made, originating in the shop as to output, actual versus estimated time requirements on jobs and operations; recording and reporting behind- or ahead-of-schedule notices, rise and fall of reject rates, etc.
9. Keeping in-process inventory records and charts up to date; posting information on progress charts and making other relevant reports to line management.
10. Acting in the name of the "router" and "scheduler" in case of emergencies (taking remedial action in the event of sudden changes in production schedules and routes); reporting changes effectuated to the router and scheduler, respectively.

Evidently, dispatching is also a tedious task interwoven with a great deal of detail work. Even though it is clerical in nature, last-minute decision making characterizes good dispatching, since the dispatcher is the last link in the chain between performance and planning.

Let us consider the above ten points in some detail. The importance of the dispatching function to the orderly flow of job shop operations becomes apparent when some detail is given and the student becomes familiar with the forms of originating in the dispatching section.

FILING

At the time the production of an incoming order is planned, old contracts tend to be in some stage of development. As the days go by, orders are gradually closed out. Most production plans are made relatively far ahead of actual starting of operations. These orders represent the backlog of a manufacturing company. Thus, when business is good, a plan made today may not start until 6 months later.

It would be unwise to turn over the production schedules to foremen so many months ahead of the scheduled starting date for various reasons: 1) the contract may be canceled in the meantime, 2) the foreman might forget about the order or mislay the processing instructions which go with the order (job cards, blueprints, and so on), 3) priority orders require a reshuffling of existing schedules, and 4) the customer may increase or reduce the order, any one of which would necessitate additional planning effort. To prevent mixups and delays, dispatchers act as file clerks and hold on to production plans until the day arrives to put the plan into practice.

Supervisory personnel should receive their assignments (authorizations) only a day or so before the operation falling under their jurisdiction should commence. As a result, the foremen will not be overburdened with work related to advance planning and production will never start without proper releases.

Dispatchers might develop some sort of filing system permitting them to keep track of orders classified as being 6 months, 3 months or 1 month away. They might also have a weekly and daily file of production orders. Thus, orders are placed from the monthly files to the weekly and daily file. When the day and hour are in sight, all sorts of precautionary actions must be undertaken. The later orders in the active file will get special attention. When all the necessary details are checked out and everything seems to be in perfect order, all papers necessary to execute the plan, including the authorization itself, are turned over to the foreman. Upon such authorization, action will start and production progress will be controlled. The second operation on an order will be handled through move cards, which may be handled similarly to the original turning over of the job card to the proper foreman.

ALLOCATION OF MATERIALS

On paper, every plan looks good. One of the impediments to proper execution of the plan is the unavailability of materials—parts, ingredients, components—of the right quality or quantity. It should be understood that in the planning stage, vendor's commitments are assumed to be correct. As long as records indicate that the item is on order and that the vendor committed himself to a given delivery date, production plans are made on the assumption that the goods will indeed arrive in time to start production. At the time of execution, however, assumptions are no longer admissible; only actual availability is important. Thus, prior to giving a production authorization, the dispatcher will check with the stockroom to ascertain whether the goods are actually on the shelf or in the bin. If not, it may be necessary to trace the shipment.

In the routine of dispatching, merely a *material requisition* is sent to the stockroom either in single copy or multiple copies. On it the storeroom clerk will report to the dispatcher and indicate the availability of the material in question. At the same time, the clerk might simply note that the material is "allocated." This simply means that, if another job requires the same material, he will report that material is available but has already been allocated. This may, under certain circumstances, be of considerable importance, particularly when a rush job or a priority job that must be shipped requires a material which is supposed to be used a few days later on another job. The production department may, however, decide to take the material which has already been allocated and hope that in the meantime the material replenishment arrives so that none of the jobs will have to be halted. However, someone knows that one order was robbed at the expense of another and can always make appropriate arrangements to avoid further trouble. At any rate, when the material is available, the dispatcher knows that as far as materials are concerned, operations can commence.

Barring the possibility of order robbing, the chances are that when a materials handler is sent to the stockroom to pick up the material to be deposited at the machine where it will be used, disbursement can be made without delay. The material has already been taken down from the shelf and deposited near the door or window where it will be disposed of against either the requisition form or a copy of it.

Occasionally there may be a slight discrepancy between the quantity to be disbursed and the quantity that is available. Metal pieces, for instance, are not actually counted but are merely weight-counted. Since there may be scrap in the material, the weight-count may show more pieces than are actually available. Also, pilferage or wrong posting or something else may create such a situation. The fact should not be forgotten that most small-cost items are purchased on the basis of an agreement that, say, 5% of the material may be rejected. If a plus and minus agreement was made, it can happen that there is 4% to 5% more or less in the bin.

TOOL REQUISITION

Job shops use the same equipment for a multiplicity of purposes. For this reason equipment must be set up prior to operations. The tools to be mounted on the machine must be available; otherwise, they cannot perform the operations designated by the schedules. Therefore, the dispatcher has to make certain that the toolroom actually has the tools needed.

A tool requisition, in single or multiple copy, is sent to the toolroom, which will inform the dispatcher whether the requisitioned tools are available. When they are, the dispatcher knows that tools will not hold up the operation in question. What happens to the setup job is another matter, and this will be explained subsequently.

Setup Requisition

When the tools and everything else are available, there is nothing in the way of production. But tools must be mounted on the machines as the operation requires. Unless the worker is responsible for his own setup, the dispatcher must requisition the setup from the setup supervisor. In a large company separate men are assigned to set up jobs. When the requisition is made and the setup supervisor promises that a given tool will be mounted on the machine at a given time, the dispatcher's responsibility ends. From there on he assumes that setup will be taken care of.

When setup commitment, or for that matter any kind of commitment, is made, it is advisable to sign and countersign forms. The reason for this is that the signature of an individual is evidence that he has assumed responsibility for the assignment.

Preparation of Production Papers

The route sheet contains all information necessary for production; nevertheless, it is essential that it be broken down into its component elements. As said before, the reason for this is that the individual foreman is interested only in that aspect of the route sheet which concerns his department. Hence, the route sheet will be broken down into job cards (work cards). Each operation will be individually listed on a job card and will contain, among other data, the name of the customer, the part and name of the operation, operation number, production quantity, hourly output quota, and starting and finishing dates. The information must be adequate to get production rolling. In addition to the job card, the dispatcher prepares time cards, move cards, inspection tickets and any other papers which might be necessary to inform everybody who is concerned.

Each foreman is given a set of papers. As far as the foreman is concerned, the turning over to him of these papers is similar to giving a test paper to a student. When the student receives the test paper, and the questions, he knows what must be done. So does the foreman, and he knows what has been assigned to his department and when he has to start on it to get it done when needed.

TRAFFIC REQUISITION

The raw material available in the storeroom is not going to get to the workplace by itself. Someone has to pick it up and take it to the machine where it is needed. The dispatcher sends a requisition to the traffic supervisor and encloses the raw material requisition already initialed. The materials handler picks up the raw material against the material requisition slip and deposits the material as ordered at the place indicated on the traffic requisition slip. The plant is usually divided into work stations, and each work station has a numerical designation. This workplace number might be written on the transportation requisition to inform the materials handler.

The same thing applies to moving materials from work station to work station. When the material should move to the next workplace, a materials handler is instructed by the dispatcher's office where to pick up what and when. Then the work in process is deposited at the designated place.

WORK AUTHORIZATION

The fact that everything has been taken care of indicates that the production schedule is still all right as originally planned. The material is ready and has been dispatched to the work station; the setup man has fixed up the machine so that the operator can run it; etc. Now that the date has arrived, the supervisor is going to get the operation rolling. The work authorization and everything which goes with it has been turned over to the supervisor in charge of the operation approximately a day before.

The rest is up to the supervisor. He decides which workman is to do the job, and he must explain what has to be done and how to do it. This is supervision! Details about supervision will be given in Chapter 16.

RECORDING FACTS

Dispatching is a desk job. It is usually done in an office located in the shop. At any rate, facts to be recorded are bound to come from the production shop. Therefore, a carefully developed communication system must guarantee an uninterrupted flow of information from every segment of the shop to the dispatcher's office. Occasionally, timekeepers are hired to assist the dispatcher in collecting and transmitting information that originates in the shop.

In the absence of timekeepers, the information can be written down on various forms, also prepared by the dispatcher's office, either by workers or the foreman, or occasionally by inspectors. The forms are subsequently deposited in designated boxes to be picked up from time to time by someone from the dispatcher's office. Thus, through this system of communication, the dispatcher is always informed what happens in the shop. Since time is the essence of orderly production, supervisory personnel are instructed to get in touch with the dispatcher by telephone, telautograph, teletype, or by any other appropriate means to make sure that vital information reaches the dispatcher's office quickly. At any rate, the communication system between the shop and the dispatcher must be an excellent one if dispatching is to fulfill its intended purpose.

Because of the need for perfect information flow, it is customary to decentralize dispatching. When decentralized dispatching exists, each department might have its own dispatch center. This has its advantages and also its disadvantages. Speedy information flow is guaranteed and departmental problems are quickly and expediently solved. Decentralized dispatching is, however, less effective in the coordinative sense because total information is dispersed throughout various dispatch centers. Its efficiency is enhanced, however, if a central office is still maintained.

CHARTING PRODUCTION FACTS

Production data become meaningful only through charting. Charts depict the aggregate situation in visual form. It should be understood, however, that it is by no means necessary to chart production data. It is merely suggested that through charting, related facts become more meaningful than numerically presented data.

Two kinds of basic information must be carefully posted unless data processing machines make this function unnecessary. They are *ouput data* and *progress* against the schedule. The latter must be posted operation by operation.

Cumulative totals of output figures gain importance when scheduling repetitive lots. It is important to know the cumulative production totals so that the still-remaining production lot can be determined. Recording of in-process inventory, however, becomes particularly important in repetitive production. About this more will be said in the following chapter.

In turn, the posting of production facts, particularly the completion of operations, on progress charts gains importance in view of the expediting functions, which is discussed in a subsequent paragraph.

EMERGENCY SCHEDULING

If time is the essence of production, rerouting and scheduling are important ingredients of dispatching. Last-minute changes will be performed by the dispatcher. Machine breakdown, employee illness, accident, materials shortage, and similar happenings might complicate execution of predetermined plans. To prevent delays, it is imperative to take immediate action without a great deal of red tape. To be more specific, the remedial action is in the hands of both the supervisor *and* the dispatcher. Whereas the supervisor would see the situation from his own perspective, the dispatcher always knows the overall situation and will advise a remedial action which best fits into the overall picture.

To keep the record straight, any changes initiated by the dual efforts of the dispatcher and the line supervisor must be reported to routing and scheduling immediately. The reason for this is obvious: since allocation of equipment is his function, the planner must know about every change because it will influence planning in the future. Longer than anticipated occupancy of a machine will precipitate shifts in production schedules at a later time. Delays in any one of several related operations will cause mutual delays in assembly operations in general and shifts in departmental work loads in particular. Thus, it is imperative to give immediate notice to schedulers and routers about changes which were made on the spur of the moment.

EXPEDITING

If the progress of orders operation by operation is charted, the progress chart will always be a replica of the existing production situation. Thus, the expeditor checks where delays are and investigates their causes. Remedial action can then be taken. Any remedial action would, of course, also involve both the supervisor and the dispatcher.

The modern expeditor is quite different from his predecessor. In the past, an expeditor responsible for a product or some part thereof pressured the job under his jurisdiction through the shop. In a sense, expeditors were the ones who, through moral persuasion, forced production supervisors to schedule production according to some sort of a priority system. Thus, a waiting line developed and expediting assured that nothing was forgotten.

Since production is nowadays carefully scheduled, expediting has undergone structural changes. Thus, the function of modern expediting is to follow up orders and make certain that everything is on schedule. Therefore, expeditors will check only on those jobs which appear on the control board as behind schedule. A periodic look at the progress chart will indicate which job is or is not on schedule. A telephone call, a personal visit to the department in question, or a contact through any other means might clear the issue with the supervisor whose department is involved. (See Figs. 9-8, 9-9, and p. 390.)

Expediting is a hectic as well as an interesting activity. Expeditors must to some extent exert a friendly "pressure" on supervisory personnel by reminding them that certain operations must be accomplished, yet expeditors have no authority whatsoever over line foremen. For this reason, expeditors must be jovial fellows who know how to get along with production men. They ask favors rather than pressure men; they request and remind, rather than order people around. Obviously, this function must be carried out with a great deal of tact and understanding. This is one of the many areas in which good human relations is of paramount importance.

Skillful expeditors are capable of keeping the flow of production moving and can more or less assure the accomplishment of production plans in the manner determined by production control. Actually, the router and the scheduler perform the planning and the dispatcher and the expeditor perform the control aspects of production control work.

The student might ask why expediting is necessary at all. If we assume that planners base the production schedules on facts and dispatchers make sure that nothing goes wrong, how is it that expediting is still needed? The answer is that a production shop is a busy place and, since people are involved, to err is only human. Errors, last-minute happenings, and many other impediments might cause losing track of a production order. Unless someone is in charge of the various products, orders might get permanently lost. Thus, expeditors are "fathering," so to speak, given products and seeing to it that everything under their jurisdiction moves according to plan. By abolishing the expeditor's job, under the assumption that good scheduling is in itself a guarantee of good production, we may fall into the common error of assuming that perfection is possible. It never is. The need for expediting lies in the relative unreliability of the human factor of production.

In practice, there may be either departmental or product-centered expediting. In the former, one sees to it that products to be worked on arrive in time and also that completed parts leave the department according to schedule. The product-centered expediting, in contrast, cuts across departmental lines; the expeditor follows the product through various departments. Product-centered expediting assures that materials enter and leave the plant on time, that is, in accordance with previously established schedules.

SUMMARY

THE PRODUCTION CONTROL FUNCTION IN INTERMITTENT JOB SHOPS

The intermittent job shop has a functional plant layout. This implies that a given type of machinery is lodged in a given department. Thus, if a product must go through different machines, it must also be routed through various departments. Since the same equipment is used on several orders, a time schedule must be established in order to avoid two jobs being assigned to the same machine at the same time. Functions of routing and scheduling will then set up a theoretical production flow. This is the plan which the production foremen must subsequently execute.

Since the plan is on paper only, many unforseen factors capable of preventing the execution of the plan might enter the picture. It is the combined function of dispatching and expediting to see to it that everything necessary to performance is available where the execution of the plan requires it. Therefore, dispatching and expediting are control functions. They assure that the plans will be carried out according to predetermined plans.

THE PLANNING FUNCTION

Routing and scheduling can be considered the planning aspects of production control. Routing established the path by which the product is to move in the production process. It sets the designated operation sequence and assigns specific machines to operations, including alternative machines. Along with each operation, information necessary to carry out the production program is listed: time standards, setup time, work station and number, production quantity including the allowance given to compensate for the reject factor, and economic lot quantity if the item is produced in lots rather than in a lump sum.

The routing function tends to coordinate the activities of many other departments, especially those of engineering and industrial engineering. The coordination is incidental, however. The router does not coordinate "people"; he merely pulls together information—which, in turn, is the result of efforts of people—and by virtue of summarizing related information on a piece of paper he actually fulfills not only the planning but also a coordinative function.

In the planning effort, scheduling is the most important element; but, of course, routing must precede it. The timetable or schedule is the result of careful planning effort. The schedule fits every incoming order into the overall production plan. Unless every new job can be fitted into the company's already existing production program, the contract cannot be accepted. One alternative to refusal is to subcontract those operations the company cannot handle and distribute the rest of the operations to the various departments in accordance with the machine time availability. The main function of scheduling is to keep downtime on machines to a minimum and get the most mileage out of company facilities.

THE CONTROL FUNCTION

The function of planning is control. Assuming a reasonable amount of perfection, thoughtfully determined plans tend to guarantee performance. Theoretically, the plan is a sufficient guarantee that everything will move in the shop according to a predetermined pattern. In reality, however, this does not necessarily happen. The reason for nonconformity with plans might be that the plan is based on foresight and, in a dynamic economic life, foresight is difficult because change is the only constant in life. Thus, a customer may cancel his order, a machine might break down, or an accident might cause delays. When any one of the above impediments to production enters the picture, the plan must be adjusted. Indeed, we never, or seldom ever, accomplish exactly what we have planned to accomplish. Yet, this should not discourage the planner. The fact is that until something happened, production went according to predetermined plans. Thereafter, a new plan is made and, until something makes the planner change the plan the second or third time, everything will move in an orderly way.

The function of dispatching and expediting is control over performance of previously established plans. The dispatching function checks on all sorts of details, and by doing so it makes certain that all the prerequisites of production are there: the raw materials are available and will be transported to the machines as needed, the tools are available and will be mounted on the machines when performance is to take place, all necessary information is made available to supervisory personnel sufficiently in advance to let foremen staff their department, and every form or paper is prepared. The dispatcher is the one who makes last-minute changes possible, yet assures performance on schedule by giving the go-ahead sign to supervisory personnel.

Expediting makes sure that nothing is forgotten and that everything moves according to plan. The main task of the expeditor lies in occasional bottleneck-busting. Production might stop for some reason or other. Any substantial time waste can cause serious interruptions in the flow of production. Thus, to avoid far-reaching delays, any problem which might hold up production must be eliminated. It is the function of the expeditor to find bottlenecks and suggest ways to eliminate them. Whether the problem is solved through overtime work, rerouting of work, or by any other means is immaterial as long as the cost involved in the solution is less than the costs which would have resulted from the bottleneck situation.

Dispatching and expediting guarantee that the production plan, prepared on the basis of accurate information but weeks and months ahead, always conforms to the existing situation. Hence, errors resulting from inadequate information at the time of planning are eliminated and plans are brought up to date. In this sense, the dispatching and expediting functions can be considered complementary to routing and scheduling.

THE PAPER WORK SYSTEM

Production control is done through a paper work system. The plans are made on paper, yet production takes place in deeds, not words. To assure that there is a two-way information flow to and from the shop, a system of paper work must be developed.

QUESTIONS

11-1. Looking at things from the point of view of production control, what distinguishes a typical job shop from a production shop of either the repetitive or the continuous variety?

11-2. What does the term "order control" imply?

11-3. What information must production control gather in an intermittent job shop prior to developing a production schedule?

11-4. What is the function of bidding in intermittent job shops?

11-5. What is involved in estimating in general and cost estimating in particular?

11-6. Explain the possible consequences of errors made in estimating.

11-7. What is the role of the production control department in estimating?

11-8. Provided charts are used by the various members of the production control staff, which charts are capable of facilitating the production control procedure?

11-9. What are the functions of routing, scheduling, dispatching, and expediting in intermittent job shops?

11-10. What is the relationship between inventory control and production control in a pure job shop?

11-11. If scheduling is based on accurate time study, to what extent is it necessary to have expediting?

11-12. Under which conditions is it impossible to have a centralized production control so that scheduling and dispatching must therefore be entrusted to operating foremen?

11-13. When would an ordinary job shop split a production order into economic lot production quantities?

11-14. Can the inventory position be the basis of production in a pure job shop?

11-15. What is meant by overlap scheduling and what is the purpose of such a scheduling method?

11-16. What role is played by sales forecasting in a pure job shop?

11-17. How can a "production flow" be established on paper?

11-18. What factors must schedulers take into considerations at the time production schedules are established?

11-19. Is it often necessary in intermittent job shop operations to change and rechange production schedules? Explain.

11-20. If the production schedule at the end of the month does not resemble that of at the beginning of the month, what sense is there to elaborate production scheduling?

11-21. What is the basis in job shops for the determination of job priorities?

11-22. To what extent is it advisable to build "time tolerances" into production schedules to accommodate the possibility of delays, rush orders, and the like?

11-23. Is it absolutely necessary to appoint separate individuals (or a group of individuals) for routing, scheduling, dispatching, and expediting work or can some other arrangements be made through which equally good solutions be designed?

11-24. What is the relationship between the various members of the production control department if a functional separation of the production control function exists?

11-25. If repeat orders are frequent and relatively voluminous, what arrangements should a job shop make to cut operating costs more than would ordinarily be possible with small-scale methods of production?

PROJECTS

11-1. Select a typical job shop in your community and through the company's public relations department, arrange a visit to the plant. During your visit with the men in the production department, persuade them to supply you with the various forms or charts used in that company to plan and communicate the plan with shop personnel.

Once in possession of these forms and having seen the charts used in the planning process, place the forms in a scrap book and indicate the function each form fulfills. Finally, make a flow diagram indicating the flow of paper work from the production control department to the various production departments and other departments relating to manufacturing. If the form is made out in multiple copies, also indicate where the duplicates or triplicates go and the reasons for them.

11-2. During the suggested visit to the job shop, try to strike up a conversation with foremen and find out from them what they consider to be their duty in respect to production planning and control. Also find out how much power the departmental foremen feel they have to plan their departmental work loads and to what extent they are obliged to follow the instructions of a central planning group.

11-3. Try to establish the relationship between purchasing and engineering departments in a job shop and determine in what way and to what extent these departments are complementary to the work of the production control department.

11-4. Suppose you are invited to be a consultant to a typical intermittent job shop having 15 production departments and only one assembly department and, in turn, each department has approximately 15 pieces of production equipment of essentially the same type but of different vintage. What kind of production control system would you say the plant needed if a) the company as a whole has a $12 million business per year, b) averages 50 to 80 orders per year, and c) employs 500 machine shop and 150 assembly workers in addition to 50 indirect workers (materials handlers, setup men, maintenance men, etc.). You should also be informed that the plant in question has only historical time study data at its disposal (based on cost accounting records), and the mode of communication has in the past been based more or less on word of mouth.

11-5. Assume the same situation as in Project 4 except that the company handles 2000 to 3000 small orders per year, each calling for a few to a dozen, but seldom more than a hundred units. The plant has excellent time studies and a piece rate system.

CASES

11-1. Tailpipe Twisting Machine Company

Located in Detroit, the TTM Company is engaged in the production of automotive parts. While most manufacturers in the Detroit district are engaged in the manufacture of new parts and accessories, TTMC is in the replacement business. It makes primarily tailpipes, mufflers, and exhaust system accessories. The best customers of the company are the automobile companies, but most of the nation's garages and dealers may turn to TTMC if a replacement part for an old model is needed.

"The postwar boom is long since behind us," stated the president of the company recently, "and the much heralded boom of the sixties is not making very much noise. This is favorable for us on the one hand, and it brings problems of magnitude on the other. The fact that more and more automobiles are on the road is good for us, and the fact that money seems to be scarce currently in the pockets of most automobile owners is also good, because replacement of tailpipes, mufflers, and the like are needed in greater and greater quantities. At the same time, the tight money situation created problems recently because of short-run orders which cannot be produced profitably. Although more business is done today in our plant than ever before, the profit margins are now thinner than ever before in the company's 50-year history."

When an exhaust pipe or any part of the exhaust system gets rusty and wears out, dealers turn to companies such as TTMC and order a replacement for the pipe, muffler, or whatever part of the exhaust system it may be. In turn, the dealer or the garage must have obtained the order from an automobile owner who returned to his dealer to get a replacement part for his car. It is obvious that most automobile manufacturers do not carry in stock tailpipes for, say, a 20-year old model and will have to order them from a supplier such as TTMC. The problem of replacement becomes more and more complicated as the models grow older, and a pipe for a 25-year old model must be made specially, because no one keeps such an antiquated part in stock.

The common characteristic of all orders which TTMC obtains is that the tailpipe has to be built in accordance with customer specifications. It might come as a surprise to some people that each model and year necessitates different exhaust pipes. Thus, over the past 40 years or so, many different tailpipes have been used. There are even today over 500,000 25- to 30-year old automobiles on the road. Thus, a large number of different tailpipes have to be produced by the Tailpipe Twisting Machine Company. For instance, during the month of December, 4050 different tailpipes were ordered and delivered in accordance with specifications. The differences in tailpipes are those of size, twist, number of twists, pipe diameter, and thickness of raw material. All these must be according to specification.

A bit further explanation is necessary at this point. Although each tailpipe is different, some degree of similarity has existed among tailpipes. Nevertheless, it is safe to state that, regardless of how well styles and types of tailpipes have been standardized, there are at least 900 to 1000 different tailpipes in existence. This figure will, of course, increase with the passage of time. During the 1962 model year, for instance, General Motors and Ford combined added approximately 50 different tailpipe combinations to the already large variety of types, sizes, and twists of exhaust pipes.

In view of the steadily growing variety in exhaust pipes, the cost of making tailpipes, mufflers, etc. started to increase; yet owing to severe competition, prices charged for tailpipes had to remain pretty much the same. There were many other companies in the country (as well as in the Midwest) giving severe competition to TTMC. Basically, the original manufacturer's list price was the guiding principle. The garage could obtain the part from the automobile manufacturer (which often turned over the order to TTMC) at a list price, but often had to wait much too long to satisfy the automobile owner's delivery requirements, particularly in states where inspection requires replacement of faulty exhaust pipes. In such instances, the garage or the dealer turned to the Tailpipe Twisting Machine Company.

The order had to be executed at the list price, unless the customer was willing to pay more for fast service. Ordinarily, however, fast delivery had to be made anyhow, because this was the only means of making customers come back again and again. Thus, delivery had to be made both at given delivery requirements and at a fixed price. While, in the net, the same thing has been true in the past as it is now, the difference is that in the meantime costs of production have gone up, the nature of demand has undergone substantial structural changes, and as a result, the tailpipe business is no longer as lucrative as it once was.

The recent recession created a situation which the TTMC had never experienced before. This started with a drastic change in dealers' and garages' purchasing policies, according to which most exhaust-pipe customers discontinued ordering large quantities—even of the commonly used tailpipes—and instead, started to order from 1 to 5 units at a time. In the past, it was rare that a dealer ordered less than 25 of a commonly used type of pipe. Apparently, the general scarcity of money in dealer's hands forced dealers to change from quantity purchases to hand-to-mouth buying.

The upshot was that such customer policy began to severely influence the costs of making exhaust pipes. In the past, the company could always stretch its deliveries a bit because most dealers and garages usually had a sufficient number of pipes in stock to stand a delayed delivery. Now that the dealer had only one or none in stock at the time the car owner ordered a replacement of his tailpipe, rush orders became not the exception but the rule. The company was flooded with rush orders which had to be manufactured in "single" pieces rather than in "lots" on the one hand and with overtime work and pay on the other. Furthermore, the constant change from the production of one type of pipe to another required a great deal more setup time (and cost) than before. All this meant that downtime was excessive and was cutting into the plant's capacity to produce and that the company could not lump together orders of similar or identical twists to run them through the shop with one setup.

To illustrate the severity of the situation, it is essential to know that the shape and form of the twist, in addition to the number of twists, is different in most tailpipes. The machines performing the twisting operation have to be adjusted for different twists. While it is not too time consuming to adjust the twisting machine, there is a great deal of difference when 5 pipes go through the same twisting than when a considerably larger lot, say 200, goes through. Twisting 200 pipes with one setup is quite profitable, but when for five or even one piece the machine has to be adjusted, the production time per unit increases tremendously. Apparently the only solution to the problem as far as the company can see, is to raise prices; but, unfortunately, competition prevents this approach.

Because the average wholesale price on tailpipes varies from $10 to $20, it is advantageous for a dealer not to keep any tailpipe in stock as long as fast delivery can be made. Evidently, a replacement garage such as one at Sears, Roebuck and Company would have to keep thousands and thousands of different tailpipes in stock to make a sale, which constitutes a substantial capital investment in inventories. A smaller garage could possibly ask the customer to come back two to five weeks later and could still make both the sale and the installation. By ordering only when the customer called for a tailpipe, the dealer or garage has no capital investment in exhaust pipes at all; but, of course, a rush order to obtain a tailpipe creates a serious production problem in the tailpipe manufacturing plant.

A recent order from a Pittsburgh dealer-garage for two tailpipes, one of them for a 1943 Chevrolet, is a case in point. The dealer specified that delivery must be made within 8 days after the issuance date on the order, but at any rate before the next expiration inspection date on The Pennsylvania State

Motor Vehicle Inspection. Apparently, the customer had to replace his exhaust pipe to obtain the inspection ticket for his car before the inspection deadline expired. Since the dealer has been one of the best customers of TTMC over the years, it was necessary to meet the customer's delivery requirement. It was obvious that a loss would result from the order as specified.

Although the Tailpipe Twisting Machine Company produces many commonly used tailpipes to stock, any tailpipe older than 10 years has to be made when the orders come in. In the past the company has accumulated four or five orders before it set up the twisting machine (thereby raising the production run), but with the rush orders, this method could not possibly be continued without taking a chance that the customer would become dissatisfied and never place further orders with TTMC; and the same thing was true as far as the price was concerned. In many cases it was evident that the costs of production would exceed the revenue from an order, but as the case of the Pittsburgh dealer-garage indicates, it would have been unwise to raise the price on the tailpipe to the dealer and thereby take a chance that he might take his business elsewhere in the future.

The production process of twisting pipes into specified shapes and forms is relatively simple, but each pipe variety has to be handled on an individual basis. First of all, the precut pipes are taken out of stock against a sales order slip which also serves as the production authorization. The sales slip is amended by the routing department with information on length of the pipe, required gage of the pipe, type of raw material, and the diameter of the pipe. Although within limits variations are not serious, a heavy pipe requirement could not be satisfied with a thin pipe delivery without being rejected by the dealer. At any rate, the dealer must be supplied with what he needs for his customer's car. The specification as far as the pipe is concerned can be found in the specification books of the automobile manufacturer and are filed in the planning office according to make, style, and year of the car.

At the bending areas the pipe is heated before the machine can perform the bending operation. The gage and diameter of the pipe are important because there is a relation between heat, diameter, and gage of metal and bending. The wrong pipe, even though the required diameter, could easily be spoiled and scrapped. Thus, the codification and picking out of the stockroom the appropriate tube and setting up the machine according to the type in question are of paramount importance.

The pipe would fit into the automobile as long as the length, diameter, and configuration were suitable for the car in question. The critical department is the twisting department, where the heating and the bending operation take place. The cutting department saws the pipes according to normal pipe needs and in large scale; when tailpipes for model T Fords are requested, even the cutting operation has to be done piecemeal. Annealing is also done on large scale in the annealing room without regard for the pipe or the customer.

While the similarity among several pipes permits some degree of lumping of orders together, the discrepant delivery requirements makes this practice difficult, if not impossible. Also, care has to be taken when performing the twisting on pipes of different diameter and gage because the heating time (and therefore also the bending time) takes somewhat longer for heavy-gage pipes than for thin- and light-gage pipes. As far as the workmen performing the various bending operations are concerned, they need to know only three basic facts about the order: 1) length of feed to the machines between bends, 2) polar rotation, and 3) angle of bend. The latter can vary between as little as 0.36° and as much as 180°. Although the average tailpipe contains only eight bends, it is conceivable to have up to 13 or 17 turns in a pipe—particularly in foreign-made cars. Occasionally, the worn-out pipe is sent in with the order, because that is the best way to instruct the manufacturer about the length of the pipe and the nature of the bend which has to be made in the pipe.

When the tube has finally been twisted through several machines and achieved the necessary shape and form but an excessive length has developed because of unduly high metal elasticity, the pipe has to go back to the work area where cutting is done to reduce the length to what it should be.

To combat the profit squeeze, several measures are contemplated, some in the area of process development and some in the area of production control. Thus, process engineering has suggested the consolidation of several operations. In the past, each bend was made in stages (first bend, second bend, final bend) because the metal could not immediately be bent 45° without breaking. To make bending faster, that is, to bend it with one operation rather than gradually until the required degree of bend is attained, sand or a mandrel is placed in the pipes to keep them from collapsing at joints when the bending overtaxed the metal's elastic limits. Despite some benefits, this method had to be abandoned because the filling up the pipes with sand or mandrel took more time than the savings attained in cutting down the number of operations. Thus, the plant returned to its original method.

According to the processing method, first bending of the "first twist" curves the pipe only a gentle 10° etc. until the desired bend is attained. The pipe passes through the same machine several times until finally the last bend gives the pipe the final twist.

The crack which results from fast bending is also caused by the lower quality of metal which has recently been used to lower the costs of production. Apparently neither the use of low-grade metal nor improvements in production technology could solve the problem.

To document the generalities with something more tangible, cost cutting could be attained via several methods of production control. While the savings attainable would come from various cost centers, the aggregate of all small savings would deserve attention because it would represent one of the last opportunities to lick the profit squeeze. Basically, the production control department would have to create "artifically" larger production lots; otherwise, it would be necessary to prevail upon customers to increase the size of their orders from current levels to the levels of the past. It is apparent to the company that the furnaces would be used to advantage only on very large orders. Also, the setup costs on the benders would be substantially reduced. By reducing the downtime on these machines, greater mileage could be gotten out of each bender.

The production control department has a general idea about the various possibilities, but it still has to work out the details of control. In the main, the system would permit sending pipes through in large lots, but separating them at later stages when extra bends and curvatures could be made on smaller machines. This reasoning originated from the contention that pipes can be classified into similarity groups. According to a statistical sampling method to check on the feasibility of the idea, 50% of all pipes were found to go through the same first bend, 25% of all pipes the same second bend; the rest of them were the odd-shaped exhaust pipes. Furthermore, about 40% of all pipes have the same fourth bend irrespective of the shape and form of the pipes.

Further study revealed that nearly 50% of all business still comes from large orders. These are placed by the various assembly plants (Ford, Chrysler, General Motors, American Motors, etc.) and from big mail-order houses or dealers. Thus, the above-mentioned problems could be considered somewhat less acute than originally assumed.

The suggestion that the later bending operations should be performed on smaller bending machines has been taken under advisement. Nevertheless, the proposition requires acquisition of new equipment. Some engineers suggest the possibility of numerical control of the bending process, which would introduce automation in the Tailpipe Twisting Machine Company. While the latter has some merits, the investment might be too great in such a job shop as TTMC. However, if a production control system could solve the problem the company faces at the present time, no additional investment into equipment would be necessary. On the average the company's facilities are 8 years old and depreciation is based on 20 years.

The details of the production control system capable of solving the problem at hand have been turned over to the head of the production planning department. Top management requires of the production control department a more detailed study than has so far been made of the similarities between exhaust pipes, the degree of frequency between the similarities, and the rate of arrival of new orders. Once these observations are made, the production planning department must develop a complete explanation of how it intends to accomplish the production control function and overcome the problem caused by the sudden change in dealer purchasing policies. At the same time, the planning department should determine the increased paperwork which might be involved and appraise the costs (clerical costs associated with production control) and the savings. While the company is by no means pessimistic about the future, and probably has no reason to be, it seems fair to say that it has to face the present situation with realism. It cannot be assumed that dealers will return to their old buying habits once they realize that they can accomplish their business objectives without having large stocks of tailpipes tying up their valuable working capital.

Questions. The case clearly indicates that the problem of the company started with a recession-induced new purchasing policy on the part of customers. Evidently, the company cannot ignore the situation, because it has serious effects on its operations and, in particular, on its cost structure. The profit squeeze is, accordingly, very severe as far as Tailpipe Twisting Machine Company is concerned.

Since the technical solution has failed to accomplish its intended purpose, the student should not attempt to check further into that matter. Anyway, that is a technical problem and business students should not tackle it. Thus, the main task the student should tackle is to see whether a production control system could create larger production runs, at least at some stations, and accelerate production and reduce, at least in some instances, the requirement of new setups. Obviously, also a codification and an elaborate paper work system will be involved.

1. Check the symptoms which indicate that the problem is acute enough to require immediate attention.

2. What are the underlying causes of these symptoms? (You may agree with the statements made in the case, or you may have your own ideas as you analyze the case description).

3. After analyzing the company's current situation, what production control system (paper work and planning work) do you suggest that the company adapt to alleviate the situation and bring about lower costs of production? Explain the production control system in great detail, including the forms which must be used. Furthermore, explain why you believe that the system you propose will help the company to combat the profit squeeze.

4. Do you think that outside factors indicated in the case are indeed so powerful that the company would not be able to solve the problems precipitated by them "from within"?

5. To what extent do you agree with the findings of the statistical study of similarity among tailpipes and in what manner should the company make further studies to gain additional insight into processing similarities and foundations for a simplified production process using a carefully developed paperwork system?

6. This question should be answered after the student has learned something about the various control techniques when orders are repetitive in nature. Which control techniques contained in Chapter 12 are applicable in the TTMC case and to what extent can stock items be produced?

11-2. TYMCZUK AND COMPANY

Tymczuk and Company manufactures pumps, filters, and cooling systems designed to regulate the flow of liquids in general and to help recirculate or transfer fluids in particular. While the company has a history of operations in the United States that goes back only about 15 years, it can look back to a very successful decade with pride. During its short existence in this country, the company has developed several fully new concepts in pump design and improved old pump models with the use of its own Polish patents. Thus, the company has established a reputation for products of great efficiency and durability.

From booster pumps, condensing units, heat exchangers, package liquid coolers, centrifugal pumps, and oil-less air compressors on, most products of the company have a wide variety of industrial uses. They are employed to handle municipal and industrial wastes; their usefulness in construction work or in any other kind of pumping operation where heavy liquids or sludges must be disposed of is unsurpassed by any other competing product. Where water, petroleum, cleaning solvents or any other fluids are to be pumped, no other device is known to be in existence which can do a better job than, for instance, the self-priming and straight centrifugal pumps made by Tymczuk and Company. In addition to qualitative excellence, the company's pumps are available in a wide variety of types and capacities. Among other industries, the petroleum industry relies heavily on Tymczuk pumps in both field operations and distribution. These oil refinery units are very popular, since competition in this particular field has been practically nonexistent as a result of a skillful accumulation of patent rights by the company. The only other firm who could successfully compete has been preoccupied with measuring instruments, rather than products dealing with the pumping problem as such.

The company was started by the late Stanislaw Tymczuk in the vicinity of Krakow, Poland, and specialized in the production of oil regulating pumps and gadgets sold primarily to the various oil refineries operating near Ploesti, Rumania. Even during the German occupation, the company prospered, since Germany depended largely on Tymczuk products. The approaching Russians in 1944 forced the company to relocate its plant facilities to Austria and subsequently in Bavaria. Finally, when the convertible deutsche mark replaced the defunct reichsmark, the sons of the owner sold all plant facilities and converted their holdings into dollars. Vladimir Tymczuk, one of the four brothers, had, in the meantime, emigrated to the United States and set up operations in a formerly government-owned plant bought at a reasonable price. By 1950 he operated a highly efficient shop employing nearly 500 people. By the time the whole family had emigrated, the four sons of the late Stanislaw Tymczuk started cross-licensing their patents and developed a large line of products; one of these is a pump widely used today in the booming private swimming pool business. The profitability of the latter resulted in a quick acquisition of wealth.

In 1952 the company incorporated and went into the production of various items based on a 220-page catalog.

Even though production was based on catalog items, the operations of the company were essentially of the job shop type. With the exception of swimming pool pumps and cooling systems, most items were ordered in single or multiple units, but always in limited quantities. For that reason it was not feasible to produce stock items. Each customer had certain special design specifications, even though they ordered something from the catalog. Furthermore, the cost of each item was relatively high and it was cheaper for the company to produce as customers order rather than to stock up on any one of their pumps without having a customer for it. Certain parts which were standard and were common to several of the pumps were stocked. The motor, which was also a part of the finished pump, was usually purchased from an electrical manufacturer. As far as Tymczuk and Company was concerned, production consisted of assembly of purchased or company-fabricated parts. A great many of the machined parts were fabricated in the company's Midwestern plant.

Although a nonunion shop, difficulties were occasionally experienced with the labor group. As a rule, however, employees were satisfied, since the company made it a point to pay approximately 20% higher wage rates than the union rate in the community. Thus, the company succeeded in keeping out the labor union. Employees were mostly immigrant craftsmen (primarily of Ukrainian extraction) since the owners liked to speak and give instruction in their native tongue. All four brothers operating the plant were Polish-or German-trained mechanical engineers and knew their business in every respect.

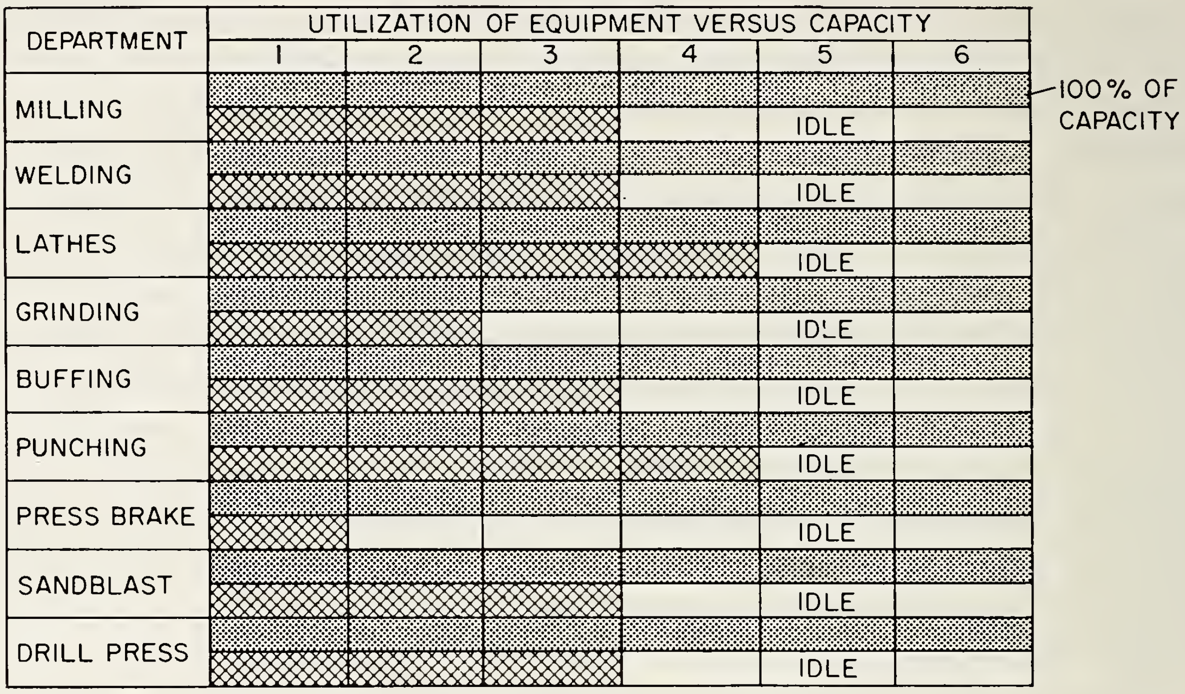
The products of the company were composed of a multiplicity of machined parts. Several Chicago foundries and a Chattanooga forge shop supplied the company with castings and forgings; the basic raw material used for the pumps and company-manufactured items was cast or forged aluminum, iron, or certain alloys. The items fabricated by the company moved in the process of production from operation to operation and were finally assembled into a finished pump. Since each operation might be a different one, the product was moved from department to department where the equipment needed was located. It was not unusual for a given part to go through 15 or 20 different manufacturing operations before final assembly could take place. A great deal of back and forth transportation took place, since the departments were scattered all over the plant. However, the plant layout arrangement was such that those departments which are most likely to depend on one another were adjacent.

As a result of the success of the swimming pool pumps and selected cooling systems, a large segment of the plant was tied down with production of various parts for pumps, circulating units, and cooling systems. These parts were prefabricated since the customer had little, if any, special desire in the way of specifications. Out of every month, the swimming pool circulating pump and the cooling system business required about 10 days' plant capacity. The rest of time, the facilities were busy with custom pump jobs. Business was so good that even during the recession of 1959/60 many millions of dollars in backlog orders were accumulated. As business improved in 1961, the company was forced to institute multishift operations to work off the large backlog.

Since commitments were based on guesses rather than systematically developed plans, many orders were sadly neglected. Thus, sales offices had constant trouble with impatient customers. While the owners were excellent engineers, they had very little experience with production systems. As far as production was concerned, the company's foremen decided what should be produced and when. Thus, everything depended on the skill and experience of supervisory personnel. Work was usually completed first on those items which had a "very angry" customer; whoever hollered a lot, got his pump. As long as a large part of the employees were fellow immigrants, a certain teamwork developed and production somehow kept up with demand. The orders, however, exceeded the plant's normal capacity and it was difficult to turn out more than that normal capacity. Since at the present time the number of plant employees has reached the 3000 mark, of which only about 40% were foreign born, the originally established teamwork among these men has gradually diminished and production has fallen more and more behind previous performance records.

To alleviate the situation, company officials have contemplated either plant expansion or a better utilization of man-power and facilities. Whichever solution is more feasible will be put into practice. To find out what would be the most desirable course of action, the company hired the services of a reputable consulting house. The consultant's main task was to discover the reasons for the company's inability to meet its commitments in time. Thus, he had to determine whether there was indeed a slowdown in production or whether company facilities were no longer adequate to handle the growing volume of business. The Tymczuk brothers contended that an expansion would cost much more than they were willing to spend at a time when businessmen throughout the country seemed to wonder where the economy was heading. Furthermore, they thought that an expansion would add facilities to plant operating capacity which to them seemed to be ineffectively used. But since record keeping and red tape were kept at a minimum, it was difficult to determine the factors which caused deliveries to fall behind schedule.

The consultant started his investigations by collecting and organizing scarcely available production data. It was fortunate, however, that the office kept records about production time spent on each and every piece part. Also, fortunately, records of time requirement for assembly were available. Even though the records were not in perfect shape, the total time required to complete each order was available. These records were assembled and separated according to order numbers, and then the latter were classified into months and weeks. Finally, the actual time required for the operations were compared with the monthly and weekly capacity of each department. (Departmental capacity can be considered as being equal to the tallied capacities of individual machines.) The results of the investigation were plotted on charts. The chart for a sample week is shown in the accompanying illustration.



According to the consultant's observations, the plant (based on 100% capacity versus actual capacity utilization) was definitely underutilized in the sense that less than full capacity was used. This report surprised the owners—even though they felt also that the equipment was ineffectively used—since they were under the impression that equipment was used *all* the time, including during Saturdays. The booming business of the company more or less guaranteed Saturday employment to every employee on the payroll. It should be noted that it costs the company 50% more to work on Saturdays because of the common practice of paying higher wage rates for work beyond the normal work week. The chart indicates the available capacity versus the capacity which was actually utilized on a given week. While the chart is merely a sample week, the various charts reconstructed for every week of the past year showed a pretty similar result.

The chart is, of course, an oversimplified presentation. To construct the chart, it was first essential to determine (on the basis of predetermined time standards) the time standard for each operation performed by machines during a given week. If 100 different jobs were assigned to a machine per week, the time standard to perform the jobs in question was tallied. Subsequently, actual machine utilization expressed in minutes was collected and added up. (The basis was the time card filled out by workmen or shop foremen). All work assigned to a given department was then added up. Finally, the chart was divided into six days and all six days were assumed to be 100%. If the actual time required represented only 50% of the total machine or departmental capacity, the chart indicated that the department or machine was used only the equivalent of 3 days whereas the machine's potential capacity was six days. This, of course, does not necessarily—though it might—imply that the worker took so much longer to perform the job; rather, it implies that the machine was in operation only during a portion of the work day. Presumably, the machines were idle during several hours between two assignments. It is apparent that because of downtime or other inherent inefficiencies machine capacity has not been utilized up to 100% of capacity.

The evidence collected indicated to the consultant the nature of the problem. However, since this case is prepared so that the student is obliged to suggest solutions rather than hear and pass judgment on the consultant's conclusions, his suggestions are omitted. On the basis of the above findings, the student should draw his own conclusions.

Further investigation revealed that production foremen received the blueprint of a particular pump part falling under their departmental jurisdictions at the time an order came in. Since order was based on a known catalog number, it was a simple matter to distribute the design specification to the foremen concerned with it. It was usually distributed from the office where a file clerk picked out the necessary blueprint from a large number of prints on file. The same clerk placed the print into the mailbox of the foremen in question with an appropriate remark given to the file clerk by the sales department. The sales department usually made a statement relative to desired delivery dates, such as: complete the order not later than June 14, rush, rush, rush, etc. Since foremen were familiar with the pumps in question, they got together every afternoon and discussed the jobs which awaited quick action. Though highly informal, these meetings resulted in some sort of a schedule.

When the file clerk distributed the blueprints among the foremen involved, the sales department had already ordered the forgings, castings, or other raw materials needed for production and assembly. It was customary to turn over the orders 3 days before arrival of all the raw materials.

The materials were ordered from predetermined suppliers who had the molds—Tymczuk and Company owned all its molds and lent them to foundries. Since only one or two items were ordered at once, the forge company or foundry could ship almost immediately. These were repeat orders and required very little preparatory work on the part of the foundry or forge shop.

It was the duty of the foreman to start the operations in line with the agreement which was made in the daily meeting. When special consumer desires were specified, the foreman visited the department concerned and special favors were informally taken care of.

The foremen went to see whether the raw material was available in the stockroom. The tools were stored in the toolroom. Tools had to be given to the production foremen when a given operation required them. Since the jobs have more or less repeated themselves, workers operating the machines usually set up their own machines and completed the assignment without a great deal of instruction on the part of the foreman in charge.

If the foreman had to complete several pumps with identical parts or several orders for the same pump (but from different customers), it was his job to combine the production of several orders. Occasionally, foremen held up completion of an order because they heard from the sales department that another order for the same pump was being contracted. Thus, they delayed production of an item in order to combine two or more orders. Such action, of course, caused delays in shipment but substantially reduced the cost of production, eliminated multiple setups, and speeded up the operations involved considerably. Occasionally, production foremen decided to gamble on producing extra parts if another contract for identical parts was in sight. Ordinarily, however, stock production was the exception rather than the rule.

As a result of improvising in the manner mentioned above, the stockroom held a large number of stock items which "did not move fast enough" to warrant their storage. At times, however, the availability of a part—based on a faulty judgment in some past production periods—saved the situation and permitted quick shipment. Stock clerks often complained that all sorts of prefabricated parts for which no demand existed were in the stockroom. Some parts lay around for years before an order on which they could be used came in.

As a third part of the investigation, the consultant assembled the various orders filled by the company during the past 2 years. The orders were then separated according to products. The product groups were then separated into size, model, and standard components which they contained. Finally, each item was measured as a percentage of total production, both in dollar value and in quantitative terms. It was found that the percentage for a given kind of item was nearly identical year after year and that more than 50% of the company's output consisted of 15 specific types of pumps but that the rest of the 50% varied widely. (The investigation neglected the swimming pool items about which exact records were available.)

The consultant's last investigation concerned the profit produced by each item. This was one of the most difficult tasks, since no records were kept except for income tax purposes. Therefore, only indirect measurements were possible. Since the company had a list price, the consultant tried to determine the difference between list price and costs of production. Raw material prices were, however, readily available from the sales department which, at the time it received an order, also issued the purchase orders. Unless the predetermined vendor changed his price, the raw material price remained fairly constant. The labor cost, as mentioned previously, was available from time cards which also gave the name of the operator performing the job. The office gave the wage rate received by the employee performing the operation and the time spent on the job; multiplication of the two was the labor cost. Assembly time was ascertained in the same manner. It was difficult to determine the setup time, because one never knew what percentage of the time in excess of standard operating time was spent on setup and what part was spent on horsing around.

Since the company calculated administrative overhead (150%) and plant overhead (200%) on the basis of the labor cost, it was possible to make sample calculations on many jobs. Based on these comparisons and computations, profit margins turned out to be much smaller than estimated by the Tymczuk brothers. Thus, the conclusion that profit should have been much higher than was attained indicated a serious lack of control over the costs of production.

The consultant set up a comprehensive program to solve the problems of the company satisfactorily. His preliminary report indicated a reduction in the cost of production on the one hand and forecast a 45% increase of the company's productive capacity on the other. A complete elimination of Saturday work and elimination or reduction of costly overtime work was foreseen.

Questions. The preceding case study has purposely left out certain conclusions originally part of the case. Particularly omitted is that part of the case in which the consultant's thoughts and ideas were presented. This has been done for one basic purpose, namely, to prevent the student from agreeing or disagreeing with the solution of the consultant. What is really desired is that the student draw his own conclusions and develop his own solutions accordingly. For that reason, only the methodology used by the consultant to arrive at his conclusions has been presented; both the nature and results of his investigations are described without giving away his solutions. Thus, an attempt is made to force the student to draw on his own ingenuity in order to suggest a comprehensive plan on the basis of the findings presented in the case.

The serious-minded student familiar with situations of this kind can readily see the problems awaiting solution. Hence, to him suggestions will come relatively easy. Here the skill of the student is being tested. He must draw inferences from results and information made available to him by an experienced investigator. To most students, the nature of the investigation undertaken by the consultant might be indicative of causes to be eliminated in the future. The inexperienced student should, however, take time and think out the *why* and *how* of the investigation as conducted by the consultant.

1. What are the symptoms indicating that the company is not operating as efficiently as it should operate under the assumption of proper methods of production control?

2. In your analysis of the company's operations, what would you say are the factors which tend to cause these shortcomings?

3. If you were in the position of the consultant, what suggestions would

you make to management to eliminate the shortcomings apparently inherent in the company system and remedy the situation at hand, that is, meet production schedules without overtime work and pay?

4. Design a system of production control which would easily guide production throughout the plant and would, at the same time, cut operating costs in general.

5. Should Tymczuk and Company relate inventory control and production control work in view of the fact that many component parts are both standard and interchangeable?

6. Give an estimate not in dollars, but in possible savings expressed in man-hours of labor which would eventually result from the system you have suggested.

7. Analyze the company's production control methods from the point of view of general principles of good production control practices in enterprises engaged in the same type of production as Tymczuk and Company.

8. Design the forms and charts which you would suggest the owners employ in the planning and control procedure. Indicate the function of each form and chart.

11-3. Garment Trade Equipment Company, Inc.

Started in 1927 with 200 employees in a 38,000 square foot operating area, the Garment Trade Equipment Company grew into a large supplier of machinery for the garment industry. Originally, the company produced small machines for the then just-starting hobby trade. After a period of consistent growth, the company's products became more and more complex and the product line became wider. To satisfy today's customer demand and to meet competition, GTEC manufactures more than 300 styles of replacement parts for approximately 40 million machines currently in use throughout the country and the world.

While the garment industry is the major sales outlet, the shoemaking, seat cover, furniture and upholstery concerns, and many other nongarment trade industries rely on GTEC products. Normally, the export business is also of some importance.

The company's main plant is in a large Midwestern city and consists of a large number of buildings. Adjacent to the main fabricating building is an L-shaped structure where partially processed parts, subassemblies, piece parts, and finished products are stored. Most dealers do not carry component parts for replacement purposes, but here in the middle of this L-shaped fabricating area are stored parts needed to repair every model of every machine that might require service, some of which are as much as 30 years old. Finished products are stored in major cities in public warehouses or are on dealer displays.

Although there are only about twelve major items, with the innumerable combinations of standard parts and the special parts which different customer orders require, the number of styles exceeds the 300 figure. In other words, the GTEC custom-makes any machine for sewing purposes in accordance with consumer specifications. The special parts or attachments are also manufactured by the company.

According to a highly generalized description, the company produces machines capable of performing 50 different operations in lockstitch and chainstitch blindstitch-type machines, blindstitch tacking machines, button sewing machines, and combination seaming and pinking machines. A large number of attachments facilitate trimming and seaming, hemming, serging, gathering, ruffling, two-needle overseaming, attaching zippers, etc.

While the company finished the decade of 1950–1960 with considerable financial success, the growth of the company was not accompanied by a corresponding amount of profit. Particularly during the recession of 1957/58 a sharp decline in sales was registered which was accompanied by an even sharper decline in profits. Fortunately enough, the company was able at that time to make significant internal economies which prevented profits from falling proportionately. Figures 1 and 2 illustrate this very vividly. Thus, the Garment Trade Equipment Company, along with the rest of the industry, entered the new decade of the "competitive sixties" with hopes and fears. Its president declared recently:

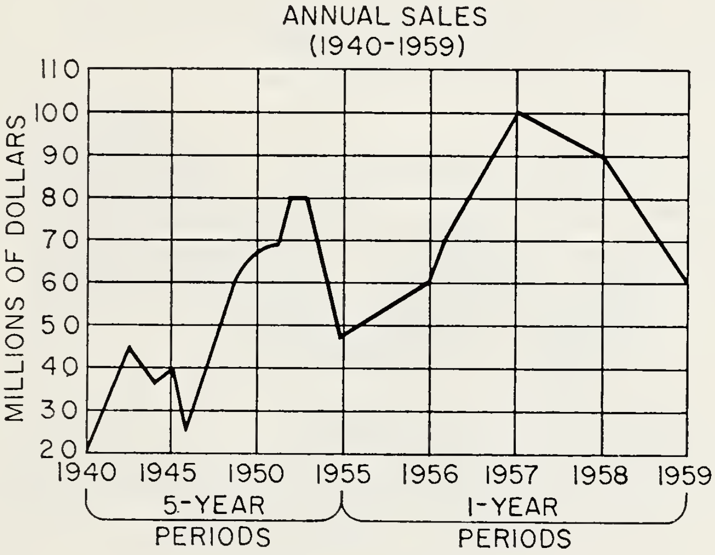


Fig. 1

"We face, with business in general, many challenges—challenges which we are not quite prepared to meet. The cost-price squeeze ahead of us will be more severe than ever before in the history of this company. Last year we suffered losses in some areas, but due to the standardization effort, overall results were still quite gratifying. This year with a severe recession on our hands, we face an even greater challenge. Rising employment and material costs, in addition to a faster than normal plant obsolescence, are responsible for this situation. Nevertheless, intensified competition at home and abroad plays an important role in that increased labor and materials cost cannot be passed onto the customer. Furthermore, the level of taxation and the inadequate depreciation allowance add 'fuel to the fire'. The garment trade machine industry faces a problem similar to that of the steel industry in that the legal depreciation rate does not permit adequate recovery of capital which is invested in plant facilities. Thus, during the past two years we had to cut our quarterly dividend rate and use profits toward rejuvenating or replacing worn-out equipment. The only way to combat this situation is to increase the production efficiency."

In spite of mounting difficulties since 1958, the company has been able to operate profitably. Much of the profit resulted from a continued and deliberate effort to standardize the number of components of new products and design a greater number of interchangeable parts, assemblies, and subassemblies. An attempt was made in the sales department to convince customers to use company-made standard attachments rather than add specially designed parts to the otherwise standard sewing machine of any one of the 12 basic models.

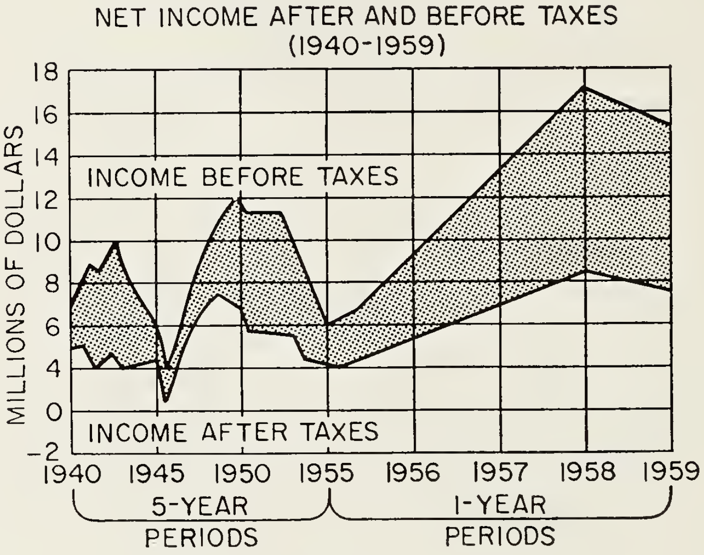


FIG. 2

In view of the stepped-up effort in standardization, a study was made which revealed that 70% of all products contained only standard and interchangeable parts made by the company and 30% of all shipments contained a large number of special parts.

It was apparent that the control of the combination of different parts was the most difficult problem, and it was suggested that by improving the method of control, along with parts standardization, production economies could be attained. The parts were combined to meet the customer's specifications. Obviously, depending on the purpose for which it would be used, the machine had to be suitable to any given sewing operation or to several different operations.

As the year progressed, the recession became more and more acute, but by the middle of 1961 reports were circulating that the revival was well underway. Nevertheless, according to the president,

"Business still seems to be on a sort of plateau. For all I know it could start up tomorrow. On the other hand it could stay on this plateau for some months to come. There is still much idle capacity in the country and severe pressures on the economy, and there is nothing to indicate that they will be relieved at any early time. Although we are holding our own, whether the dividend payment will be met depends largely on the ability of the production organization to cut costs even more than in the recent past. The standardization program has brought some results, but more standardization is needed in the future. Why we emphasize cost reduction now more than in the past is, of course, a good question, but, shall we say, we have been through a period of rapid expansion. And while we have always tried to be cost-conscious, there are, at times, other things that are uppermost in the human mind. The exigencies of the past few years have focused our attention more acutely on running very well the ship we have; now we have to do both, run it well, but at a considerably lower cost."

In spite of extensive efforts, some elements of costs rose during recent months rather than fell. Thus, for instance, the company's production capacity was only partially utilized, yet overtime work was quite high in some departments. In some instances, the company had to subcontract orders at a time when people were laid off in many departments.

Investigations revealed that this situation resulted from severe marketing difficulties. The sales department, in their eagerness to obtain orders, promised *anything* to prospective customers: prompt delivery and as many special parts as they wanted. These were very expensive promises, because to meet delivery commitments (or face cancellation in midstream), it was essential to work overtime even though during subsequent weeks men had to be sent home owing to lack of work. Spurts in production had to be evened out, but the present production control system did not permit such an "orderly scheduling."

After the receipt of an order, the sales department turned it over to the engineering department to find out whether the specifications of the customer could possibly be satisfied from standard piece parts. If they could be, savings in production time and in price could be attained, because cost of the piece part as special would be much greater than as standard.

The sales department agreed with the customer on a price without consulting the production department, except when a special part was involved. In such instances, the blueprint of the latter was sent to the superintendent of production who took a "professional" guess and gave a price on the part or parts in question. Otherwise, the price of the item was based on standard costs. Since most parts used in the various sewing machines were standard, everything could be based on the standard cost data. Assembly time, however, was estimated; and to get the labor cost, estimated assembly time was multiplied by the assembly wage rate average. The price of each unit, based on the standard cost of parts, the assembly cost, and the standard overhead expenses, was negotiated with the customers. While price quotations were quite good, all quotations were based on one-shift operations; but quite frequently the product could not be completed on normal shifts. When overtime work was necessary to make a shipment, the costs were considerably higher than reflected by standard cost data.

Internal communication was poor. The sales department worked independently. Decisions were made without consulting the production group. This was particularly so during recession periods, which have been quite frequent in recent years. Nothing was written down, and the telephone was the key to company operations. Thus, for instance, if the part which went into the product was "extra," engineering did not report back to sales, but sent the prints directly down to the shop stating that "this part cannot be satisfied from standard stock items."

Although there was a production manager charged with production planning and control, he was usually informed *after* an order was obtained. A sales order on which bid price and delivery date were given was sent to him. It was up to him to make the item at that price and at the date specified. He was concerned with all assembly operations as well as with the fabricating of the "specials."

Inventory control (parts control) departments worked independently under the assumption that they were responsible merely for providing parts (only the inventory items, not the specials) when the assembly departments needed them and at the same time keeping the monetary investment in parts and stored subassemblies at a minimum. The inventory control system worked with the minimum-maximum method. When an item reached the predetermined minimum, the stock clerks automatically placed a purchase or shop order to replenish the inventory items. The minimum quantity (reorder point) was based on 5 weeks safety quantity plus the rate of use during the lead time. Although there was an economic quantity which was often in excess of the quantity to be ordered when minimum was reached (safety plus rate-of-use volume), this rule was not something which had to be obeyed. The shop people had a substantial leeway as to how much they should make.

Unless specials had to be made, the production manager was merely concerned with scheduling the assembly of the sewing machine on order. Presumably, all parts were available in the stockroom. If specials were also involved, he scheduled the manufacture of specials first and, when they were completed, assembly schedule had been established.

Although standard parts should always be available, it happened quite frequently that the stockroom reported back to the production manager's office that a given part was not available. This usually happened a day or so before assembly work was scheduled to start. Unless another order could replace the one thus delayed, workers were laid off until the "missing parts" became available. The shortage was handled on the same basis as if it were a special part. If the item was a purchased item, the purchasing order asked for immediate delivery. If the part did not arrive as expected, there was a shortage and assembly could not start until the part or parts had arrived. Workers, as in other situations, had to be laid off because of lack of work. It must be apparent by now why so many jobs became rush orders and had to be pushed through both manufacturing and assembly departments with overtime work and pay. Yet overtime pay was often cheaper than another day of delay.

In the fabrication of specials or rush orders difficulty was often experienced with raw materials. If the material was not available in form of sheet metal, bar stock, casting or forging, procurement was turned over to purchasing. Thus, a rush order could have been further delayed. When it finally was started, it was labeled "rush rush."

Generally speaking, the sales department gave such short delivery dates that scheduling of everything meant nothing but rushing orders through the plant. The frequent difficulties with special parts and part shortages, in addition to the rush orders in the assembly departments, led to classifying many shop orders as "rush rush rush." These had top priority. While this was the result of competition, "this rush business is costing us our profits," stated the president. Evidently, when plant capacity did not seem to be adequate in a period of recession, the question was "not capacity, but the inadequate use of that capacity."

Since in recent years too many jobs were accepted with too many specials attached to them, the problem of handling the special parts became quite acute. The operation times on specials were only guesses rather than time-study-supported facts; the production process was also haphazardly determined on them and it was impossible to allocate work loads in the various machine shop departments in accordance with an orderly system. Since the production manager found out only from foremen that the inventory control department had issued shop orders directly to them[1] (thereby tying down some of the key machines), it was impossible to know in the production office when and whether machine capacities were available. Furthermore, the special attachments were made in multiples, even though often only one or two pieces were needed. These multiples were stored, and when replacement was requested or when a similar or identical part was used on another order, the special of a previous order was released from the stockroom as a stock item, making the time scheduled in the machine shop on certain machines in fact free. But no one said a word to the production manager about this until by accident or through a phone conversation he found out about it from someone. Thus, assembly could have started earlier had the production manager known that a special was suddenly a stock item. Actually, the reverse could also have happened.

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[1] When the bin was empty, a stock item subsequently became a rush order and had to be handled as if it were a special part.

The number of stock items grew with the production of specials. By making multiples, the scrapping of one special would not create any assembly problem because another was readily available. The spoiled item was not thrown away, however, but was kept in the bins as a stock item. If replacement was ever ordered, an immediate shipment could be made at a "big fat profit." Since specials were high-priced items, the company could charge almost any price for them. According to estimates, 35,000 types of standard replacement parts were in stock—not to count the individual (single) piece parts which were made as specials and kept wrapped up in cellophane with an identifying number on them. A book was kept on these items because only in that way would they be found in the storage room, where they were kept in little bags hanging on nails. The coding system was considered excellent, and every item could be found without delay. In case a scrapped part was in the bag, a rework was worthwhile because it was still much cheaper to rework the item than to start from scratch. The inspection tag, indicating what was wrong with it, was used as the wrapping paper. Otherwise, no records were kept on stock items. They were stored in bins in the same manner as books are stored in a library. No records were kept because the minimum quantity could be recognized merely by looking at the overall quantity still in the bin. Admittedly, the visual appraisal of the minimum was not a perfect method, nevertheless it was cheaper than record keeping. These items could not very well be stolen or otherwise pilfered, because to the average employee they were fully useless. These were industrial sewing machine parts, useless for the ordinary sewing machines owned by housewives.

According to the production manager, this was a bad inventory control system for various reasons. First of all, the size of inventory just in terms of space requirements was excessive. The rent paid for storage facilities was extremely high. The company argued, however, that in addition to giving the customer prompt service and freeing the dealer of the need to carry large inventories of parts, GTEC benefited by maintaining lower inventories in the field and at the factory. All parts ordered, unless the stockroom was short of the part, were on their way from the Midwest within 24 hours, in contrast to the time when delivery period used to take five to ten days. The argument that huge sums of money were tied down in inventories was countered with the explanation that the company recovered the storage charges (including interest) merely by overpricing the part to prevent any losses on orders for replacement parts. A replacement part for specials commanded an extremely high price.

Secondly, the production manager argued, it would be considerably more beneficial to keep a limited number of in-process materials and finish them as orders came in. As it is, a large number, at least 50% of all parts, were the same as far as the first four or five operations were concerned. Only the last few steps were different. Then again, sandblasting, annealing, and degreasing types of operations were the same. Thus, savings could be achieved both in inventory carrying charges and in operations, because the latter could be grouped and scheduled in large production runs rather than piecemeal. The sandblaster according to the production manager's observation, was always inefficiently used. The machine could sandblast items by the thousands, yet always only a bucket full of parts was completed at once, with a great waste of equipment time, output capacity, and labor cost.

Sales, via engineering, turned over the parts lists on an order to the stockroom (inventory control) and to the production manager's office. The stockroom clerk collected from the bins the needed parts into a small bag. While moving from bin to bin, the clerk noticed whether an item reached the minimum quantity. By the same token, he often discovered that the bin was empty. When the bin was empty or reaching the minimum, he wrote out a shop order. The pink shop order was written when the item merely seemed to have reached the minimum but the bin still contains some units; a blue shop order was written when the order could not be assembled owing to lack of parts. Blue represented rush, and such orders were handled in the machine shop as if they were specials.

If all parts were in the bag, the bag was placed in a drum where other assembly orders were located. The bag was tagged and the fork lift operator carried the drum to the assembly department.

Foremen received their production schedules from the production manager's office or from the inventory control department. Specifically, assembly schedules always came from the production manager's office, except when a part was not available. In that case, assembly foremen did what they could to avoid development of a bottleneck. At times they worked around the missing part and completed assembly except for placing the missing part into the unit. Often this was not possible because the part belonged deep inside the sewing machine. Thus assembly work had to be postponed until the part became available. The foreman, noticing inavailability of a bag (parts going into an order), called the production manager and asked him whether another order should be started. A quick reschedule was often successful, but many times employees had to be given makeshift assignments or be sent home.

The making of special parts was also scheduled by the production manager's office, and so were the rush orders provided the production manager knew about them. Replenishment of stock was ordered directly by the inventory control department. The foremen scheduled the replenishment orders as best as they could, but gave priority to specials and rush or rush-rush orders.

To improve the scheduling procedure, production control tried to forecast sales, but it was discovered that sales could be forecast only in terms of dollar value, not in terms of models and component parts. Since dollar value had little or no meaning to the production control group, this practice had to be abandoned.

The manufacture of special parts was based on estimated production time per operation. The assumption was made that every machine was available every day, simply because foremen had to drop everything when specials and rush jobs had to be sent through their departments. This was, however, an oversimplified assumption, because if a production lot was only halfway finished, it was unwise to stop the machines and reset them for the rush or special job in question.

Taking the approximate production time of specials into consideration, the assembly schedule was determined by the production department working backward from the delivery date stated on the sales slip. If the statement "subject to cancellation" was written on it, it was mandatory to complete the item no matter what. Overtime work was cheaper than the loss of an order.

Although the production manager's office had a load chart on every assembly department and every department of the machine shop on which work loads were charted, the charts were only partially valid in view of the fact that actual departmental scheduling (in the machine shop) was out of the hands of the production control department. Since it was up to the foreman to do whatever job best fitted his department, it was timewise not necessarily the best work load allocation. If, for instance, the foreman had 20 hours to do three jobs but started production with the least urgent one and along came a rush-rush-rush job, then the work load was completely out of balance and two or more rush jobs were created. The production manager felt that everything should go through his department, but inventory control, foremen, engineering, etc. were against it, fearing that their positions would become subservient to production control. Some groups within the company called the efforts of the production manager "empire building," and by using that accusation every attempt at reorganization could be defeated.

When something went wrong and shipment was held up by a laggard part, expeditors were sent down to the shop to make sure the part was completed and reached the assembly department. Expeditors were working for the sales department. If a customer changed his mind either to get a faster delivery than originally agreed to or an order was canceled, disturbance was unavoidable. A stop order was placed only on the assembly or subassembly, but the parts were continued in manufacture even though no longer needed. Machine shop foremen knew nothing about the change and continued making the parts; at the same time, items urgently needing the same machines were waiting and finally had to be completed with overtime work and pay. The general idea that, once started, the item should be finished was sound, but no one, except the production manager, seemed to realize that the savings thus attained were considerably less than the loss incurred by not making urgently needed jobs without overtime work. The contention that the setup was paid for and must be made use of blinded the shop people.

In view of the above, it is apparent that even in the event the schedules were realistic, departmental foremen could not meet them because of the dynamic nature of production. Orders were canceled, but no one said that they were canceled; in turn, if orders were three-fourths through, it did not pay to stop producing. Yet if a rush job came in, everything had to be dropped. The constant reshuffling of orders was far from being efficient. Nevertheless, an old practice and inadequate system of control could not be changed overnight. When business was good, things seemed to be more relaxed and less confused because the sales department did not have to make so many and far-reaching concessions in terms of delivery dates and specials.

Foremen were often at fault too. When production had to be accelerated, they had their own ideas about how to speed things up a bit. Thus, they disregarded instructions of the production manager and ran larger lots than the order called for. Foremen were old employees and had a feel for business. Thus, they made this and next week's quota in one run this week. While this obviously added to one week's work load, it doubtlessly reduced that of the next week. Employees worked on piece rate; and if workers got the maximum numbers out of a setup, the setup time otherwise lost went toward employee income. Piece rate earnings were high when production runs were doubled. Not only earnings but also production went up substantially. The trouble was, of course, that the bins might now be filled up with a given type of part or component, but the stockroom tended to run out of some other parts also in need. Employees were to set up their own machines and the setup time was always an integral part of the time standard, because it would have been awfully confusing to segregate production time from setup time. If two normal runs were sent through with one setup, a worker might have worked 20 minutes which otherwise would have been taken up by setup. The higher piece rate earnings went to him. Foremen did not mind this because it made them "look good" in the eyes of employees.

Questions. A careful analysis of the company's operations will reveal certain inconsistencies in production control in this type of operation. It must be determined by the student what these inconsistencies are and by drawing on his conclusions, he must suggest ways to eliminate them.

1. List the symptoms which seem to indicate that this company is not doing everything right (that is, in accordance with customary production practices applicable to this kind of operation).

2. What are the factors which seem to cause the symptoms listed in Question 1?

3. Pass judgment on the company's production system and indicate whether it is good or bad and what the company should do about eliminating the shortcomings of the system. If, in your opinion, the company should completely abandon the present system, indicate why. What suggestions would you make to management?

4. Do you agree with the company's estimating procedure? Support your statement with adequate reasoning.

5. Comment on the company's delivery commitments and the relevancy of deliveries and profitability.

6. What do you suggest the company do to accomplish orderly production, low-cost operations, and costwise favorable inventory policies?

7. In Question 3 you were asked to make some suggestions about a production control system. Indicate at this point the details of your suggestions (charts to be used, if any; the forms to be used, if any; the flow of paper work from department to department; the nature of centralization or decentralization etc.).

8. Indicate the role of sales forecasting, if any, in this company and pass judgment on the attempt which the production manager made in this respect.

9. Pass judgment on the various interdepartmental relationships currently in existence in this company and indicate what they should be, if you have objection to them.

chapter 12

Production Planning in Repetitive Production

REPETITIVE PRODUCTION

When demand for a given product is erratic, unpredictable, sporadic, irregular, or repetitive rather than continuous in nature, the manufacturer is faced with several problems. One of them is whether the sales volume is large enough to warrant mass-production techniques. If sales would warrant large-scale production methods but the marketing conditions prohibit continuous operation, there is still a way out, namely, repetitive production. The latter is nothing else than an adaptation of the continuous production method to the prevailing demand conditions. Thus, despite intermittent rather than continuous demand, large-scale operations are possible.

The secret to successful repetitive operations lies in the plant layout arrangements on the one hand and in clever production control techniques on the other. These devices permit relatively—not absolutely—continuous utilization of plant facilities without incurring the disadvantages of the traditional production line. Through ingenious plant layout arrangements, it becomes possible to produce several different items on the same production line as if all items flowing through the plant were standard. Thus, in repetitive production one has the advantages of intermittent production but still enjoys the benefits of mass production.

From the preceding chapter we know that the intermittent job shop converts individual machines to different uses to make possible the depreciation of capital investment. In repetitive production, not the individual machine but the whole production line is converted to secondary or multiple purposes. This requires both a carefully designed production process and, its corollary, a thoughtfully laid-out plant. Thus in contrast to the pure production line characterized by such standard products as cement, sugar, electricity, Coca Cola, and ice cubes, the plant built for repetitive operations turns out several different products. Of course, none of these products differ drastically from one another; rather, they represent variations in size, dimension, or some other minor aspect. Usually one thing, namely, the process, is common to all the goods so built. A typical product of repetitive manufacturing is the dress shirt. Although sizes, styles, sleeve lengths, and many other details of the shirts differ, the shirts are more nearly mass-produced than custom-built.

For the reasons already mentioned that certain producers prefer to operate repetitively rather than continuously, certain job shops might also adapt the repetitive methods of production. If a job shop is blessed with sizable orders which warrant expensive tool-up, special-purpose machinery, and conveyorized line layout, a way must be found to operate on a mass-production basis. One should remember that the large order does not necessarily imply continuous delivery. Rather, the contract of a job shop usually calls for piecemeal delivery suited to the customer's needs. Thus, continuous production cannot very well be practiced. Military contracts are often of this kind. To avoid feast-and-famine situations between two production runs, the plant facilities must be utilized for other purposes. Because of the large size of one or two important orders, the whole plant layout is centered around the big contract, but the facilities are otherwise used just as they are in ordinary job shops. Naturally, the production control department pays considerably greater attention to the big order than to the small and relatively insignificant ones. In other words, the big order calls the tune.

Another type of job shop is in the same predicament as the one just described, but for a different reason. If the total of all the piecemeal orders for a given item is sufficiently large to employ mass-production methods but the individual order is small, in addition to being irregular, it is apparent that neither the intermittent nor the continuous method can be considered most efficient for this manufacturer. Hence, to attain production economies, orders might be accumulated and lumped together into economic production lot quantities. In that case, to wait for orders might unduly delay shipments to customers. Instead of waiting for the actual orders, therefore, the quantity needed for economic production is added to the run and the surplus is then stored against future orders. Production in plants of this kind is bound to take place in indefinite intervals depending on the rate of order accumulation, delivery requirements, and the inventory position. One must, however, be careful that the costs of keeping the item on the shelf are not greater than the savings that can be realized from economic production runs. If delivery requirements do not permit the delay of a shipment, it is, of course, still possible to make broken lots. The latter are, however, very costly, and too many short runs would lead back to the path of intermittent production, costwise and otherwise.

Occasionally, stock production is impossible because of the differences in individual output units based on consumer requirements. No matter how minor the difference, the plant cannot take a chance on making something in advance of actual orders without knowing precisely the consumer's specifications. For example, minor chemical characteristics must be adhered to by some manufacturers. To avoid the costlier intermittent production, orders are often classified by their similarities and all similar orders are lumped together into blocks of orders. Each block is small enough to permit the control of required variations. Similarly, production of such items as shoes, shirts, and suits is broken down into economic units even though the process is more or less the same for each product, because only this way can adequate control be exercised over consumer-dictated variations. There is still a continuous flow, of course, but in this manner control over variations is accomplished.

While repetitive production takes a number of different forms, a generally recognized prerequisite to this method is the production process. Unless the process is the same, or nearly so, for all goods, the plant cannot very well be designed for this kind of operation. A great deal of standardization among component parts entering the products must take place in order to use the same production facilities, and a great deal of time and effort must be devoted to the design of a suitable production process regardless of which product is being manufactured at any given time. Accordingly, a large part of the work preliminary to repetitive operation is technical in nature. Nevertheless, production control plays an equally important role. As a matter of fact, without special production control techniques, repetitive operations would not be at all feasible. Here plant layout and production control are bound to go hand in hand.

Since repeat orders are identical to orders which were previously executed, the handling of repeat orders becomes a routine matter. This is the beauty of repetitive operation. One reaches for the route sheet and schedules a new batch when shop orders warrant, regardless of whether the shop order originates from the sales department or from inventory control.

The routing function is accomplished with the stroke of a pen. The master route sheet is pulled out of the file, and minor changes, such as the customer's name and minor product variations, are noted on it. As soon as facilities become available, the equipment time is allocated on the order, and operations can start without even consulting the engineering department.

Since orders are similar to those handled by job shops, yet there is a built-in flow as far as plant facilities are concerned, production control is considerably easier than order control—the technique used in job shop operations. Of course, depending on the variations in products and product groups, different production planning and control techniques will be used. About the various techniques more will be said later. Here, mention only is made of the fact that production control does not have to go for information to the engineering department—because the engineering details, processing, and plant layout considerations are decided when the product is made the first time—unless technological progress necessitates drastic adjustments.

Thus, the sales department fills orders from stock or passes them directly to production control. The latter subsequently prepares shop papers and instructions, and production in agreement with delivery requirements is initiated without much fuss and bother. If the plant produces to stock instead of waiting for orders, the inventory control department issues a shop replenishment order to the production control department when a preset inventory level is reached. The latter department, as in the case of a sales order, will schedule the order as soon as equipment is available. Thus, the production authorization reaches the shop through the production control department. Whether the latter receives the request from the sales department or from the inventory control department is irrelevant.

In decentralized production control (where there is no production control department as such), the sales orders or the inventory replenishment orders go directly to the shop, where they are turned over to the foreman in charge of the first work station. Once the production starts, little further control is needed, because production follows a predetermined path and each foreman will take care of production details as a matter of course. Evidently, when an order is being run the second time, everybody just knows what must be done with it. Thus, a plan is followed regardless of whether it is in the form of a master plan (master route sheet, master bill of materials, etc.). In other words, the initiation of a repeat order becomes a routine matter, the only requirement being that equipment time must be available to schedule the start of the production of an economic lot.

DEPRECIATION OF CAPITAL EQUIPMENT

It was stated in the preceding chapter in connection with intermittent operations that, in order to depreciate its value, equipment must be convertible to different consumer specifications. The typical job shop, because of significant variation in products and the small size of orders, could not effectively employ high-speed special-purpose machinery. In repetitive production, the situation is somewhat different. Here, as said before, high-speed specialized machinery *is* warranted. But in order to depreciate its value, the expensive machinery must still be convertible to prevent periodic idleness. Otherwise, during the slack season, the equipment would have to stand idle. Obviously, only equipment that is in use can earn its keep. Since special-purpose machinery cannot be converted to different uses in the same manner that the general-purpose machinery can be, it is apparent that the convertibility of facilities to different uses must be limited to minor adjustments. Nevertheless, different products can be produced with the same production facilities. When business is bad as far as one product is concerned, the plant is converted to alternative uses as dictated by demand. In this way, the repetitive producer—just as the intermittent one—is able to get good mileage out of his facilities and can therefore legitimately depreciate the value of his equipment.

The only other choice which would be at the disposal of the manufacturer who produces similar but not identical items on the same facilities is the employment of the intermittent production method. But since both the volume and the process similarity warrant more efficient equipment, he would be foolish to operate with the less efficient method. He has some headaches with the conversion, but the effort is certainly worthwhile.

It has already been explained, but must be emphasized again and again, that a great deal of engineering work and standardization of parts, components, and process is necessary if facilities are to be convertible to the production of different items. Interchangeability must be fostered.

DEMAND AND REPETITIVE PRODUCTION

Generally speaking, continuous production is possible because sales of a given product are relatively even throughout the year. Although there are minor fluctuations in demand, production to stock in slack periods and shipment from finished inventories during peak sales will permit a normal rate of production. Repetitive production exists because the sales picture in certain production situations is such that sales do not warrant sustained production and the accumulation of surpluses would cause more costs than the savings achievable by continuous operations.

There are so many different repetitive production situations that it would be impossible to reduce all the enterprises of essentially this kind to a common denominator. One thing is sure, however: any company which is not producing on a continuous basis must have a good reason for not doing so. The product may be seasonal or largely dependent on the fancy of the consuming public. Perhaps the company could produce on a continuous basis but the raw material supply is seasonal. Long-run demand and the total volume for which the facilities are built might permit efficient mass-production methods. Thus, the plant might be bigger than current demand warrants but just right for long-run demand.

In order to prevent facilities from standing idle during off seasons, the plant is usually built for the production of several different items. The word "different" should be used with care, however. The plant can handle several different products, but the chances are that production-wise all products can use the same facilities.

Some Examples of Repetitive Production

At the outset mention should be made of the fact that we are dealing in repetitive operations with *convertible* plant facilities and the various products tend to use *identical* production processes.

Repetitive Job Shop. When a job shop accepts a large order which warrants the rearrangement of its facilities and the balancing of its departmental capacities primarily to suit the production of the order, we no longer have a traditional job shop, but a plant engaged in repetitive production. It should be understood, of course, that as far as all the small orders are concerned we still have an intermittent job shop, but the large order is handled differently.

Military contracts, as elsewhere noted, frequently require shipment of the items in piecemeal rather than lump shipment. Obviously, the contracting company will tool up and rearrange existing facilities in proportion to the size of the order. The fact that facilities are rearranged and the large order will be handled essentially as in normal large-scale production does not prevent the plant from simultaneously operating on an intermittent basis. Back-and-forth transportation of the small orders will be necessary, but so far as the large contract is concerned, distances are reduced to a minimum, materials-handling devices become more sophisticated, and tools, jigs, and fixtures become more perfected. Usually, however, the plant capacity is not fully taken up by the large contract. During a part of the month the plant operates in repetitive manufacture, but when the month's shipment is produced, the machine setups are torn down and the machines are put to other uses.

The repetitive job shop, then, is no different from a pure job shop so far as small orders are concerned, but its plant layout favors the large contract. Advantage can be taken of more sophisticated methods because the size of the order warrants such arrangements. But because the contract requires piecemeal deliveries, continuous production would be impossible. In order that equipment will not go unused and costwise be less than fully allocated, the production schedules will place other orders on the machines as time permits. That setup time is involved is self-evident. This, however, is a much better solution than having excess capacity which lies idle a large part of the year. Since the contract is a one-shot affair, the bread-and-butter business of the plant is still the job shop.

Process Industries. In the steel, glass, cement, automobile, tire, and paper industries the products are made by identical production processes but the end products must possess different chemical characteristics or be constructed in different gages, sizes, or widths. In order to meet the incoming order specifications, production must be under constant control and someone must see to it that the equipment turns out the products strictly in accordance with specifications. Here the various workers must be instructed when to make the necessary adjustments.

Similar-Process Industries. Shirts, shoes, women's garments, and men's suits are made by similar operations. However, there is a great variety of style. There are variations in size such as the sleeve length of shirts; there are such differences as right and left shoes; and there are other considerations such as raw material quality and color. For these reasons, specific control systems must be developed in order to keep track of the variations without confusion in the various producing departments. Although the plant in effect custom-makes garments and shoes, the costs of actual custom-making would be prohibitive. Therefore, the product flows through the various departments and operations as if there were no differences among the various items. By sending bundles or blocks of orders through the plant, the flow of production can be continuous to some extent, but confusion in the product variations can be avoided. Of course, this system is possible because the processes are similar and differences occur mainly in minor details of the products without substantial differences in time requirements for given operations. If there are time differences, they are relatively minor.

Different Products by Identical Processes. Chemical, cosmetics, plastics, and many other industries produce end products which are completely different from one another yet tend to go through the same equipment in the same operation sequence. Possibly only the composition differs or the heat, pressure, or curing time is changed between runs, heats, batches, or mixes.

PRODUCTION CONTROL TECHNIQUES

Even though the plant is suitable for repetitive operations, it is the production control system which will attain production efficiency. The system can be simple yet effective, but it can also be rather complicated. Generally speaking, however, most systems of production control in the repetitive production enterprise are comparatively easy to administer. The system merely provides an orderly flow of goods through the plant even though the various departments or sections perform somewhat different operations on different products.

From the preceding chapter we are acquainted with "order control," which is the most complicated production control system. By that method each order is handled on an individual basis. Every operation must be scheduled specifically; the production process for each part or component must be individually designed and routed through the plant. Diametrically opposite to this system is the flow control used in continuous production. Here all products are the same and the interest lies in keeping up the continuity of flow. In the latter situation there is one single standard product and, once the plant is designed and the production line is balanced, only the rate of flow must be kept track of. More will be said about this system in the next chapter. It is mentioned here only to illustrate the two extremes between which the various production control techniques of repetitive production will fall.

From what has been said it must be apparent that the production control system in the divergent repetitive type of operations will bear some degree of resemblance to both the other two systems. Consequently, it will be a simpler system than order control, but a more difficult and complicated system than flow control. The production control system must, of course, be tailor-made for each production situation. Depending on how much variation must be built into the output units, the system will require more or less individual attention to orders going through the process of production. In most instances no name is given to these systems, but some of them may be called load control, bundle control, block control, or batch control.

ROUTING AND ASSOCIATED FUNCTIONS

From the preceding discussions it is evident that the underlying factors making repetitive production possible are process standardization and the plant layout arrangements, which must go hand in hand with a suitable production control system. Therefore, in discussing the routing function, the assumption must be made that all technical considerations were duly considered when engineering design and industrial engineering work were finalized. Also, it must be remembered that the products which are being manufactured by the plant in question were carefully selected for structural characteristics which made them suitable for the production line.

Notwithstanding preceding discussion of the above subjects, some related concepts must be repeated here in order to round out the knowledge necessary for fully understanding the routing function in repetitive-type operations.

Routing was defined as determination of the path through which the product will move toward its completion. While in the job shop each output unit will follow an individually selected route, in repetitive production all products will take the same or nearly the same route. The difficulty that is usually encountered is at the point where minor differences must be built into the product. How to cope with these differences is the task of the production control group.

Routing is not a continuous function as far as the repetitive manufacturer is concerned, because the same route sheet is used again and again once it is prepared. Because of their frequent reuse, these processing papers must be prepared with appropriate care. (If we speak of an assembly process, a master bill of materials is used instead of a master route sheet.) Barring occasional adjustments which technological progress forces on a manufacturer, routing is a one-shot proposition rather than a continuous activity. In contrast, the intermittent production process requires the routing from scratch of every new order.

If a plant can produce a different product merely by a different combination of parts, it is apparent that the design of the parts was carefully standardized and interchangeability was fostered wherever possible. The fact that a special part is occasionally needed does not prevent the plant from operating with utmost economy. The master bill of material is still the same, but the special part must be placed on the master sheet by crossing out the part it replaces.

These sheets are filed, and when they are needed for a rerun, they are reproduced with one of the wet or dry processes such as Ditto, Mimeograph, or Verifax.

THE SIGNALS TO SCHEDULING

Production cannot take place unless the production control department is authorized to make something. But how is the production control department authorized and told to start production? Obviously, the sales order would be the most common method. When the order was accepted (let us remind ourselves that it calls for something which we make repeatedly), it is turned over to production control, which will try to schedule production of the item when equipment becomes available.

But in repetitive production many items are made to stock. In that case, shipment is made from finished inventories. When the inventory becomes low, the inventory control department does exactly what the sales department did: it gives an order to the shop to produce a new batch.

Accordingly, the production department will schedule the production of an item as soon as someone gives an authorization. When the item will be specifically scheduled for production is largely a matter of the delivery commitment (or, in the case of a stock item, the need for inventory replenishment) and the availability of plant facilities. Thus, the signal to schedule production comes from the sales or the inventory control department. Occasionally, production control accumulates several orders for identical items in order to produce things in economic lots.

Production must often be delayed in order to match orders with the economic lot requirements. Because this can be a slow process, salesmen are frequently instructed to push the sale of a given item so that production can be started and customer pressure relieved. When the setup cost is high, it might conceivably be better to lose a dissatisfied customer who cannot wait than to run less than the economic production quantity. But, of course, every effort should be made to have shipments reach their destinations on time.

The situation is quite different when inventory replenishment constitutes the shop order. The inventory department will notify production control or the first-operation foreman (in case of decentralized control) that inventory has reached a given minimum and at that time place an order corresponding to the economic lot quantity. When orders are requested in economic lots, scheduling is no problem at all. Products awaiting production tend to form a waiting line, and individual schedules take place in their order of importance.

To this point we have established that production requirements are based on two sources of information, namely, 1) sales orders and 2) inventory replenishment orders. How the sales orders are handled is entirely dependent on the product. In some instances, parts may be processed up to a percentage of completion in economic lots, stored, and, when the orders come in, completed in various ways to fit diverse customer specifications. In that case, the economic lot quantity applies only to that part of the operation which can be processed in lots. The later stages might have to be taken care of with intermittent processes. The repetitive job shop might conceivably operate this way. The advantages are that larger quantities can be processed with greater degree of mass production in the early stages of production, in-process inventory investment and storage costs are minimized because stock of unique character need not be stored, and the processing time becomes considerably shorter when a rush order (or any order for short delivery) comes in. This might apply also to the production of certain chemicals the first stages of production of which are the same, while different later stages will produce different end products. The first stages might be produced continuously on the basis of a sales forecast and the finishing stages repetitively. The lipstick maker might operate that way. While it is pretty well known how many lipsticks will be consumed during the production year, one never knows the exact product mix. Therefore, the later stages are carried out by the batch process. Initially, an economic lot of each shade is made. When the inventory of a given shade is depleted to a predetermined reorder point, the inventory control clerk signals the need for that shade. Thus, it is possible that carmine-red shade may be turned over three or four times per year, whereas a pink or purple color is made only once a year. Thus, product mix can be excellently planned and controlled by inventory control.

The description of the preceding paragraph indicates that repetitive production might be connected with either continuous or intermittent production. A plant operating continuously in either the beginning or finishing stages can operate in the intermediary stages in a repetitive fashion. By the same token, the early stages of production might be repetitive in a job shop, provided that all products use the same frame or base material, but intermittent in the finishing stages.

In summary, the signal for scheduling is given either by actual sales orders calling for a certain number of units (pieces, gallons, or tons) or by an inventory replenishment order. In the latter situation, production will be scheduled on the basis of the prevailing position in 1) raw material inventories, 2) in-process inventories, 3) parts inventories, or 4) finished inventories. As soon as a predetermined level is reached, an automatic reorder takes place. The scheduling is another matter. It is apparent, however, that somehow word must get to the production scheduling department that certain raw, in-process, or finished material kept in storage is in short supply.

PRODUCING AUTHORITY

Production will be initiated by the issuance of the shop order, which then serves as the producing authority. Although it is issued by the production control department, it is initially derived from the sales order on the one hand or the inventory replenishment order on the other. Although there is not much difference between these two methods of authorizations as far as the shop is concerned, from the planning point of view there are fundamental differences. Because we are acquainted with sales orders from the preceding chapter, we shall here discuss only orders indicating the need for replenishing shrinking inventories.

MINIMUM INVENTORY LEVEL

Minimum inventory levels must be established. Although what one company considers to be the minimum another company might find too low or too high, the determination of minimums must be predicated upon certain facts relevant to the situation at hand. To some extent the item which is stored will itself determine how much is considered the minimum. If the item is purchased or subcontracted, the minimum might be quite different than if the item is made in the company's own plant. Appendix F is more explicit on this matter.

The determination of the minimum for company-made items is always dependent on convenience factors, monetary factors, storage costs, rate of use factors, and many other considerations. The ideal situation would be to set the minimum at a level which would be adequate to continue plant operations without running out of the material in question. Ideally, when the last piece is being used, a new shipment would just arrive in the stockroom. Of course, it would be difficult, if not impossible, to set minimum levels that would correspond perfectly with actual replenishment. Nevertheless, it is in the interest of overall profitability to keep just enough stock items, neither too few nor too many.

From the point of view of production, the minimum level is important because, when it is reached, *it signals the need for a new batch, lot, or bundle.* The appromixate starting date is then set by the minimum level. How much to make is a matter of economic runs. More will be said about economic production lot sizes a little later and in Appendix F.

In many companies minimum inventory levels will determine the specific item which is to be scheduled for production first, second, or third, that is, in the order of importance. Take, for instance, a lipstick maker. Since it is unknown in advance which shade of lipstick will sell better, the company is required to produce at the outset a batch of each shade. When a new batch must be scheduled for production cannot be determined in any other way than by noticing that an item reaches the predetermined minimum. How else would the cosmetics maker know which shade should be made in more frequent intervals? Thus, the inventory position is used as the indicator of the product mix. The overall lipstick sales can be predicted through forecasting (see Chapter 10 and Revlon's sales forecasting), but the color mix cannot be predicted.

In view of the close relationship between scheduling and minimum inventory levels, the question that arises is what will determine the size of this minimum. Among the various methods used, the one described in the following paragraph might be representative of current industrial practices.

Material-Short List. While the determination of a minimum by the material-short list is an unscientific procedure, it is one of the most common methods used in industry. It is an after-the-fact type of control because it may be based on reports indicating actual shortages in the assembly departments. It can, however, be based on estimated needs the assembly departments will soon experience. The material-short list might however, also be based on a visual observation. When the stock clerk disburses materials, in going through the various bins he might notice that a given material is in low supply. Upon making such discovery, he puts the item on the material-short list. The pitfalls of this method are obvious. If there seems to be a shortage of an item, it does not necessarily mean that there is actually a shortage. For instance, if only one piece part is used per completed unit and the rate of use is very low or the plant is in slack season, the bin might be nearly empty, yet in reality there is no shortage of the item at hand.

The use of material-short lists (regardless of whether raw materials, in-process items, parts inventories, or finished items are concerned) will reveal when a minimum was reached and it seems advisable to make some more of that item. It is a system, but of course not a very scientific one.

MINIMUM-MAXIMUM CONTROLS

From the point of view of production information, we are mainly interested in the minimum point; because when it is reached, the stock clerk automatically gives a reorder signal. Since this initiates production, it is essential to know how this recorder level is determined. The maximum will determine the upper limit and, in a sense,

$$\text{maximum stock level} = \text{minimum level} + \text{economic production lot}$$

In other words, when the minimum level is almost reached, an economic lot quantity is ordered. Since it will take some time before the item in question is produced, the minimum quantity depends on the manufacturing lead time on the one hand and on the safety quantity on the other. Accordingly, the minimum quantity, whether of raw material, piece part or component, or in-process inventory, should always be adequate to keep production going or to satisfy consumer needs until the fresh stock arrives. Hence, no loss of sale should result from running out of stock. As the fresh stock arrives in the stockroom, a small reserve from which disbursements can be made should still be on the shelves. That is,

$$\text{minimum quantity} = \text{safety (reserve) stock} + \text{lead time}$$

If the processing time of a batch, lot, run, etc. would take 10 days, whereas the procurement time of raw materials to be used takes 15 days and the safety quantity should be 5 day's production (5 day's possible delay), then the minimum quantity is 30 day's supply. The reasoning behind this calculation is that the production control department might not be able to start production as promptly as desired and 5 days would be a reasonable amount of time to allow for the possible delays. Of course, it is important to know the processing time for each item, because without that information the lead time is invalid.

ECONOMIC LOT SIZES

The repetitive producer tends to produce economic lots anytime an inventory item runs low, that is, whenever an item reaches the reorder level. This does not mean, however, that under exceptional conditions less than this quantity could not be produced. But it is a routine matter, after the economic lot quantity has been established, to always make economic lots.

An economic lot quantity of any given item is that which offers the lowest possible unit cost. The unit cost refers not only to production costs proper (material, labor, and overhead) but also to the inventory carrying charges. The savings resulting from larger production runs must be balanced off with the added costs of carrying bigger inventories. In other words, the economic lot will minimize the overall costs involved in the production and storage of the production lot. While this is a sound principle, it is difficult to establish economic lot sizes because the large number of cost elements that enter the picture must be correlated with one another. The bigger the lot size, the lower is the setup cost per unit of output. But the more that is stored, the greater is the monetary investment in inventories and the greater is the number of financial problems that may be encountered with storage (obsolescence, inventory carrying charges, etc.). At the same time, the greater is the assurance that the plant will not run out of inventory items.

Economic lots are not always calculated, but quite often are arrived at by mere common sense. The reason for this will become apparent after we have demonstrated how difficult it is to work out the economic lot quantity with mathematical precision. Another important reason why in many companies a merely arbitrary system is used to determine how much should be produced at any given time is that thousands of items must be kept track of and it is felt that it would be such a big job to determine economic lot quantities on each item that the savings resulting from the exact calculations would not be large enough to warrant the bother. Thus, there are two basic systems used to establish economic lot quantities: 1) the nonscientific method and 2) the scientific procedure. Needless to say, the former is based on an arbitrary measurement and the latter on mathematical procedures. The latter in turn can be divided into tabular, graphical, and mathematical methods. The nonscientific methods may be based on standard lots, dollar or time limits, commitment, or any other suitable basis. It should be understood, however, that, formula or no formula, most companies recognize the importance of the economic lot idea; they simply feel that rough approximations are in the long run just as effective as the precise mathematical production lot calculation.

MATHEMATICAL METHODS

Let us start with the mathematical methods of economic lot calculations in order to demonstrate the general nature of the difficulties which are encountered and to indicate why many companies use good approximations to determine economic lots.

The Graphing Method. The graphing method is based on cost data recorded when certain quantities were made in the past. When plotted on a chart, these costs will give the answer with some degree of accuracy. To attain perfect accuracy is difficult, because we are dealing with innumerable cost elements which in themselves have little effect on the answer; yet in the aggregate they are quite significant. If all were to be taken into consideration, they would complicate the calculations immensely. Figure 12-1 is an example of such a method..

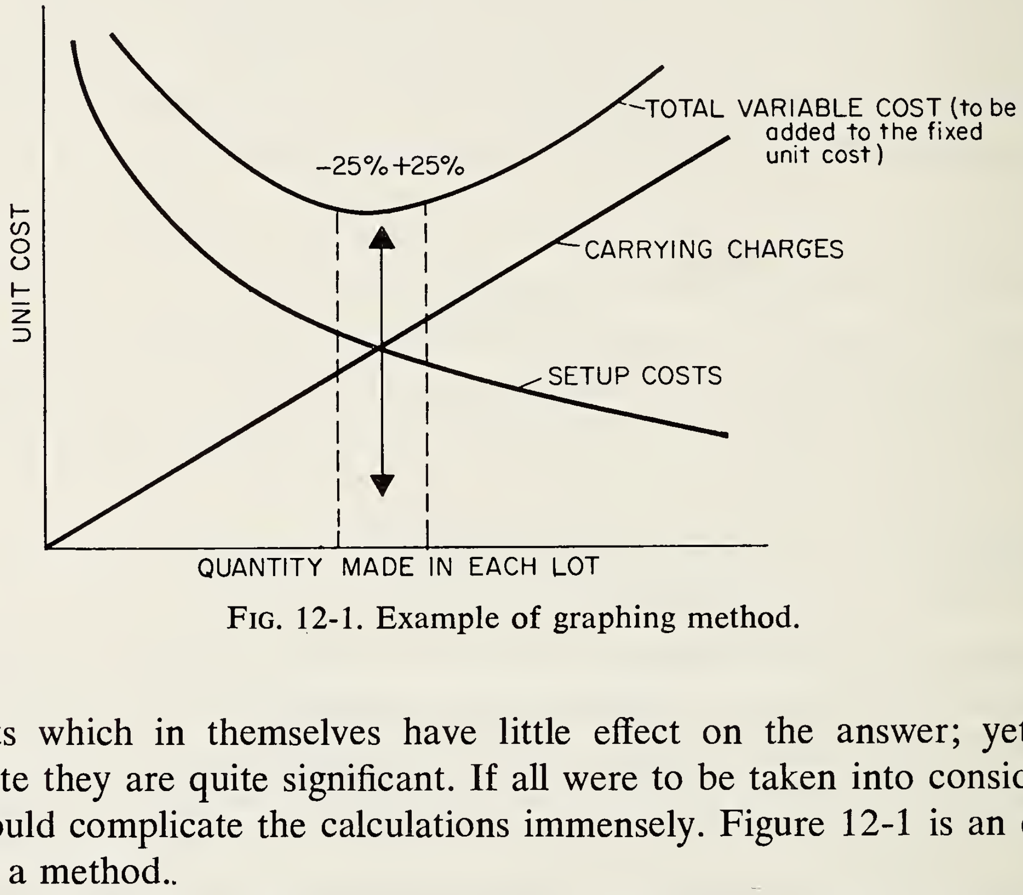

FIG. 12-1. Example of graphing method.

The Operations Research Method. Among the many mathematical methods, models, and formulas the most complex and probably the most accurate is Raymond's formula,[1] which is reproduced here in the form of an example:

Data $P = 2000$ pieces per day (capacity)

$Y_a = 1500$ pieces per day (average daily demand)

$F = D + G + O + T + S =$ cost of drawing + planning + ordering + tool-up + machine setup $= \$100 + \$25 + \$10 + \$250 + \$30 = \$415$

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[1] Appearing in *Production Handbook*, edited by L. P. Alford and J. R. Bangs, copyright 1944, The Ronald Press Company, New York, pp. 101-102.

c' = unit of manufacturing cost, $m+l+o$ = material + labor + overhead = \$0.005 + \$0.02 + \$0.015 = \$0.04

i = interest earned on capital invested = 25% for 300 days = 0.25/300 per dollar per day

$k = \frac{1}{2}$ = stock coefficient

$n = 10$ = number of batches

c'' = average unit value of each batch = m + ½ (1 + o) = \$0.005 + ½ (\$0.02 + \$0.015) = \$0.0225

$k_p = c''/c'$ = \$0.0225/\$0.04 = \$0.563

v = \$0.10 per cubic foot per year, value of storage space per unit = \$0.10/300 per day

B = cubic feet occupied per unit (assume 100 pieces go in a 1 foot × 6 inch × 6 inch box) = (1 × ½ × ½)/100 = 0.25/100 cubic feet

a' = time factor for batch production = $(1 + a_1 n - a_1)$.
Let $a_1 = t_1/t' = 0.20$, where t' = process time first batch and t_1 = process time first operation for one batch. Then $a' = (1 + 0.20 \times 10 - 0.20) = 2.80$

$$Q = \sqrt{\frac{FPY_a}{c'i\left[kP - Y_a\left(\frac{1-\frac{1}{n}}{2}\right)\right] + c'iY_a\frac{k_p}{a'} + vB\left[P - Y_a\left(1-\frac{1}{n}\right)\right]}}$$

$$= \sqrt{\frac{415 \times 2000}{0.4 \times \frac{0.25}{300}\left[\frac{2000}{2} - 1500\left(\frac{1-\frac{1}{10}}{2}\right)\right] + 0.04 \times \frac{0.25}{300} \times}}$$

$$\frac{\times 1500}{1500 \times \frac{0.563}{2.8} + \frac{0.10}{300} \times \frac{0.25}{100}\left[2000 - 1500\left(1 - \frac{1}{10}\right)\right]}$$

$$= \sqrt{\frac{1{,}245{,}000{,}000 \times 100}{0.0033\,[325] + 0.0033\,[302] + 0.000083\,[650]}}$$

$= \sqrt{58{,}650{,}000{,}000} = 242{,}300$ pieces, economic production lot or

$\frac{242{,}300}{2{,}000} = 121.2$ day's production (rounded off 122 day's production)

To develop a formula to solve production lot calculations is, of course, a difficult task. Here only the formula is given, not its derivation. It must be apparent to the student that only in large-scale repetitive production does it pay to go through such elaborate calculations. In an ordinary job shop where intermittent production of a few or possibly a few hundred pieces takes place, it would be foolish to spend a great deal of time on such calculations. Once the formula has been established, it is relatively simple, though quite time consuming, to determine economic production quantity.

Of course, there are simpler and possibly more commonly used formulas than Raymond's Formula. But we are talking about repetitive production, and here the proper determination of production lots is essential. Thus, the repetitive manufacturer might as well use one of the best of all available formulas.

NONSCIENTIFIC METHODS

While the general rule in industry is to produce at the lowest possible cost, other considerations will occasionally outweigh the principle. The point is not that the company in question would not want to attain the lowest cost, but that other elements speak against or actually prevent the application of the economic production run principle.

Standard Lot. The standard lot is in a sense an economic lot. The basis of standard lots may be a practical experience such as the fact that, statistically speaking, the tool cutting the surface of a metal wears out after approximately x number of units. Although the economic lot quantity might be, say, 100 pieces, it would pay to set it at 80 pieces if the tool wears out at approximately that level. As another example, the brick lining of an open-hearth oven can take x number of heats or hours of work. By minimizing the possibility of breakdown, a factor which has cost implications is considered and the standard lot is set to coincide with the changing of the brick lining. Another reason for standard lot might be a container, barrel, pallet, or rack which can hold only 80 pieces rather than the 100 which would represent an economic lot.

In case of a predetermined assembly schedule, such as the shipment requirement of a military contract, the standard lot can be based on the piecemeal delivery schedule of the assembly unit. Although it might be more economical to produce 100 units, convenience or processing considerations might make it more advisable to make the parts entering into the monthly assembly quota at the same rate as the shipments required. A furniture manufacturer might also use this system because of its simplicity and because in this way the various parts in process will not get mixed up or require careful inventory control procedures. Accordingly, the rate of output (from furniture parts) is always gaged to the output of the cabinet work (assembly department).

Dollar Rule. When working capital is in short supply, the lack of money overweighs the economic lot considerations. If only x dollars can be spared to invest in parts, the dollar rule applies. Furthermore, when a plant uses tens of thousands of components in the assembled item, it would be difficult to exercise control over individual items on a maximum-minimum basis. It would be a formidable task to determine the size of the minimum quantity (the reorder point) of every single component on an item-by-item basis. An additional difficulty would arise from the possibility of irregular use as, for instance, in the automobile industry, where optional equipment and accessories are used in varying rates. Thus, a dollar limit might be used as the signal for scheduling a new production run to replenish the inventory item in question. Of course, to simplify matters, a great deal of guesswork and judgment may be involved in lieu of mathematical computations. If the expected rate of use of one accessory is greater than that of another one, the dollar limit can be set accordingly. In order to keep a reasonable balance between inventoried items, the dollar limits must be reviewed frequently. The reason for this is that dollar values change. For example, a sudden change in steel, copper, or aluminum prices might seriously influence the size of the quantity to be stored. Accordingly, falling prices precipitate quantitatively abundant supply (inventory on hand); rising prices cause storage of fewer units than originally anticipated by the dollar limit.

With the dollar rule it still would be impossible to keep track of tens of thousands of individual items. Therefore, one keeps track of selected group of items likely to be affected by a change in basic raw material prices. Thus, the dollar limits must be raised or lowered when drastic changes in raw material prices take place.

When sales are highly seasonal, it might be advisable to set double dollar limits: one applicable to the season and another to that of slack periods.

A further breakdown of inventory items into cheap, medium-priced, and expensive items (A, B, C items), will set dollar ceilings strictly in proportion to the monetary investment rather than setting blanket dollar limits regardless of the per unit investment.

It must be apparent that the dollar rule is nothing but an unsophisticated minimum-maximum control. While it is not precise or costwise the best method, it still permits a great deal of control without requiring costly record keeping.

Rate of Use Quantities. The scheduling of production of parts and components can be simplified (that is, made a routine) by basing it on predetermined "normal rate of use quantity." By this system, certain items will be replaced every 2 months, some others every 3 or 4 months. Periodic reordering based on the rate-of-use quantity, just as on dollar limits, will keep the inventory level within a desirable boundary and at the same time permit an orderly scheduling of production. Whether an item is produced so that the inventory will last for 2 or 3 months depends on an arbitrary decision in which the overall cost of keeping inventories, making large enough production runs, and convenience factors will play an important role. This, however, sets not minimum points but only the output quantity which will be ordered for production by the inventory control department.

The minimum might be based on an approximation material-short list, or simply a decree that takes account of a safety cushion quantity and the usual shop lead times. The fact is that when the minimum signals the need for replacement, the inventory clerk automatically orders a 3-, 4-, or 5-month supply. Of course, this system may always be connected with a dollar rule; in that case, the policy might state something like "3 months supply as long as expenditure is less than $5,000."

It must be apparent that we are no longer dealing strictly with economic lot quantities, yet the decision is not purely arbitrary. The individual who sets the quantity at, say, 3 months supply, has good reason to pick 3 months rather than 2 or 4. Probably, the expensive item would have a shorter reorder frequency rate than the dime-a-dozen item. The shortcomings of *rate-of-use quantities* are largely overcome by combining the time rule with the dollar rule. Thus, if 3 months supply becomes too expensive because of sudden price changes, the dollar rule automatically supersedes the rate-of-use quantity.

It should be understood that without a system, an orderly replenishment of inventory items would be impossible. By using the rate-of-use quantity as the basis of shop orders, the production control department is able to develop a procedure which permits a relatively even utilization of plant factilities.

Block Orders. In certain repetitive production shops, orders are accumulated in blocks. A block is a convenient production quantity, not necessarily an economic lot quantity. Its purpose is to permit control over product variations without distrupting the flow of production. A case in point is the shoe, suit, shirt, and garment industry in general.

A shirt factory might, for instance, receive orders from different retail or wholesale outlets indicating the needed sizes, sleeve lengths, styles, and colors. For most plants it does not pay to keep shirts in stock—except for a few uniformly used sizes and sleeve length—because one never knows what will be ordered. As shirt orders come in, they are lumped together into blocks (usually the similarity of shirts will provide a natural way to classify the orders in blocks). A block might represent 2 hours, 4 hours, or 8 hours work in each department. Thus, a block is used in the same sense as an economic lot quantity, but it is based on convenience factors and practicality rather than on economic considerations. Since the setup time is insignificant, whether 2 or 4 hours of work represents a block is really immaterial as long as this quantity will permit ease of control over the variations among say, shirts.

Obviously, this system works only if there is a perfectly balanced chain of departmental capacities. The departments must always be able to accomplish the work involved in, say, 4 hours.

SCHEDULING IN REPETITIVE PRODUCTION

It must be apparent by now that scheduling in repetitive operations merely means the allocation of available plant capacity among different uses in such a manner that downtime is kept at a minimum and goods are made available as required by customer orders or prevailing consumer demand. The former refers to goods which are not produced ahead of time; the latter to shelf items.

Because the plant has been built so that there is a natural flow of goods from department to department, the routing function is evidently not much of a problem. Furthermore, departmental capacities are balanced from the outset so that each department can absorb the output of the preceding department. Consequently, scheduling is by no means as difficult as in job shops. Repeat orders are scheduled in a routine fashion, because the plant capacity is known with some degree of certainty; in job shops this is not possible because there the operation time determines how long a given equipment will be tied up with an order, that is, how long each operation, which is only a tiny segment of the order as a whole, will take at any given machine. Thus, plant capacities are more or less fixed and gaged to the product or products the plant is built to make.

Repetitive manufacturers can backlog incoming orders, but they still know in advance when they will be able to ship. The question is merely when the scheduling department will be able to make a given type of item in economic rather than broken lot quantities. Thus, production is postponed until a sufficient number of orders from each kind of product is accumulated to warrant its economic production. A block of orders is scheduled similarly except that a block contains not identical output units but only units that are easily processed together.

Scheduling manifests itself in starting dates and times. But, of course, a finishing date is implied by the fact that a second item is scheduled right after the first is completed. The starting time is, in fact, determined by the wanted date. In repetitive production, it is considerably more difficult to correlate all the wanted dates with one another. A customer may want something right away, but it often does not pay to complete any given order in broken lots. Hence, the most difficult part of scheduling repetitive operations lies in the necessity of getting the best mileage out of each setup. The scheduling will then take different forms depending on the similarities and dissimilarities among goods which are produced on the same production line. Although it is difficult to classify the profusion of repetitive operations, from the point of view of scheduling they tend to fall into the following broad classifications: 1) product cycling, 2) batch scheduling, 3) block scheduling, and 4) load allocation.

PRODUCT CYCLING

If the plant must systematically be converted from the production of one item to that of another, scheduling requires knowledge about the conversion time (setup or downtime) and the quantity wanted by any specific date. With this information the scheduling group can decide on allocating equipment time to alternate uses. This kind of situation might require the elaborate changing of tools at various work stations along the production line, cleaning the equipment between two different runs or adjusting several pressure, measurement, and other control gages, along with cleaning. It might, however, merely mean placing different units on the assembly bench. Barring running in a new product, employees know pretty well what they are supposed to do in each instance; thus, very little instruction is needed at the time repeat orders are handled.

To accomplish planning of each run, charts might be used, but they are just visualizing devices. Actual running time is adequate to determine the expected output units, that is, when the output is directly proportional to the hours worked. If we assume that x item requires 20 hours of curing time and y item 10 hours of curing time, it will evidently take twice as long to cure the same quantity of x items as y items. Let us illustrate the principle with the help of a chart, Fig. 12-2.

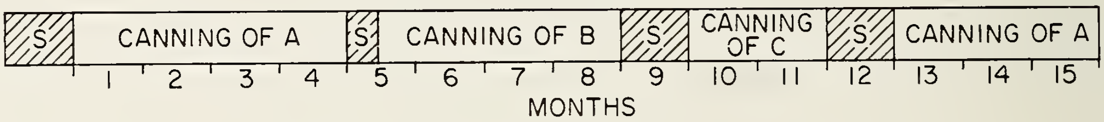

FIG. 12-2

In Fig. 12-2, the work load of the canning plant is merely allocated between different uses over a 15-month period. The conversion times are represented by S. Otherwise, the monthly output capacity can easily be allocated, because the plant can turn out per month x amount of A, B, and C canned goods per month. When the season for item A arrives again, the plant is reconverted to canning that item. This is a mere cycling of the production of different products.

On an assembly bench where hand assembly is involved, the scheduling may be pretty much the same as above, except that there is little, if any, loss of production time. The plant (bench) is able to produce four items, such as four different communication devices. The output of work station can be balanced simply by adding extra men to stations not in balance. The fact is that the product can move in the same manner as if the plant were a typical production line. If the plant turns out x number of A, B, C, and D items, then the schedule can be depicted somewhat as the chart in Fig. 12-3 indicates. It should be noted that as the front end of the production line (bottom line of

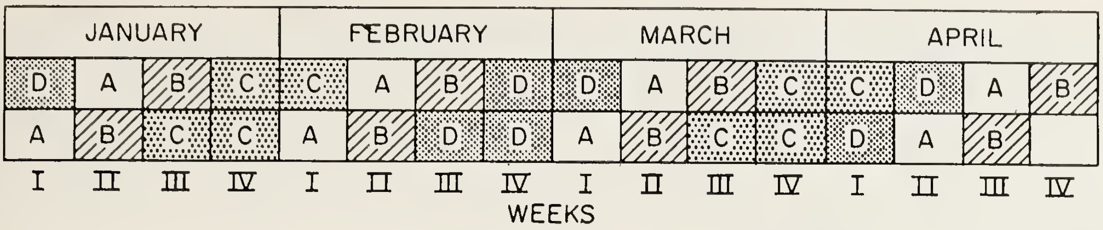

FIG. 12-3. Phasing-in in production cycling.

chart) starts on item A, the tail end (top line of chart) still works on item D at the beginning of January. Thus, shipments A, B, C, and D can be made in accordance with the wanted dates for each item. It should also be noted that at the end of each month the product cycling differs in order to take advantage of longer production runs without running the risk of added storage. Even though there is no loss in changeover time, it is better from the point of view of repetition to continue working on the same item. Such a cycling arrangement is even more significant when a setup time can be avoided by using it.

Of course, if the production run were inadequate to make it worthwhile each month, the manufacturer could double the quantity, provided that would represent an economic production lot, every second month as shown in Fig. 12-3 at the ends of January and March (item C) and February (item D). In that case a certain amount of storage cost and inventory investment would be involved. The main thing in piecemeal delivery contracts is that the required monthly quota is shipped in any given calendar month. As stated previously, military contracts are usually of this kind. It should be noted that in the case of open-end contracts the monthly shipments are irregular, and when to produce ahead of time and how to cycle the product mix depends on releases from the customer, the main contractor. Generally speaking, however, the plant—usually a contractor or supplier—can gage its own production to some extent on the customer's sales forecast. In other words, one always has some idea about future requirements and one can plan ahead with some degree of certainty.

When the production is based on inventory replenishment orders and the inventory policy calls for periodic, say, bimonthly, reordering, the cycling is pretty much of a routine affair. One expects a replenishment order from the stockroom.

BATCH SCHEDULING

Quantitative control is the domain of the scheduling function. The scheduling of needed quantities of different items must, however, be accomplished at the lowest cost. Batch scheduling permits flexibility at a nominal cost and can, in certain industries, help overcome the problem of variety in end products. Although the production process is pretty much the same for all output units, a certain operation along the way must be different. This difference can be incorporated in the batch operation.

The batching operation can be at either a finishing or a materials-preparation station. Otherwise, the plant can operate on a continuous basis, because by merely making minor changes at the batching station it is possible to turn out different end products.

In the steelmaking process, particularly when specialty steel is made, the raw material is made in special batches; but after that all operations are the same. The end product is different because the preparatory operation was different. In such instances, the batching station must be scheduled in the same manner as in order control; the rest of the operations do not have to be scheduled at all. Nevertheless, it is important to keep track of the whereabouts of the batch made from a different metal mix, because even though they are chemically different, all output units may look alike. In other words, one must pay special attention to the batching station, and from there on one keeps an eye on the product so that the various end products coming off the production line are not mixed up.

Various plants might operate in such a manner that an intermediary stage of production must be sent through a batching operation in order to attain product differences. A case in point would be the manufacture of enamel frit, in which two operations in the middle of the production process must be specially controlled, namely, the weighing out of ingredients for a specific chemical mix and the heating. Thereafter, all products move through the plant in the same way.

In a food-processing plant, the product might be identical, but the finishing stages (batching stations) will change the end product. The meat packer makes ham, for instance, in the same way, but at the curing station (toward the end of the process) changes are made in the end product. The actual canning of all products might be the same, although attention must be paid to the labeling to indicate the type of cure.

In most batching operations primarily raw materials are being prepared. The material is usually mixed, heated, or chemically transformed in some sort of vat, tank, or vessel. Usually, the adjustment in heat controls, pressure gages, or time setting must be rearranged to attain different end products. Frequently, however, only the composition of the various raw materials going into the container must be changed. The quantity the container can accommodate is usually fixed. This limits the output volume in terms of end product. Usually, however, different sized vats, ovens, and containers are used for batching purposes so that different order sizes can be accommodated.

Accordingly, if the customer wants a specific paint mixture, the paint is assigned to the batching equipment the capacity of which comes closest to the required quantity. Either two batches are made in smaller continers or batching equipment or more than is needed is made in a larger container rather than make less than full capacity. The surplus might be a waste, but in most instances it is stored in the hope of a repeat order. Storage might under certain circumstances be cheaper than making two smaller batches, even if there is eventual waste.

Now, the scheduling work in connection with batch production consists in allocating the available batch-type equipment among different uses. If the production line cannot handle the sum total of all batch quantities, a waiting line must be developed or the batching operations must work only one shift and the continuous operations two shifts.

A great deal of common sense is applied to the order in which the various batches are assigned to the available batching-type equipment. For instance, in a food-processing plant two materials that are incompatible cannot be run in sequence. Whereas tomato paste can be run before making tomato soup, tomato paste cannot be run before making cream of mushroom soup. Where pigments are involved, light colors should not be run after dark colors, but the gradations in shading should be kept in mind. In chemical plants, the schedule should be so arranged that the material made first is easily absorbed by the succeeding material without harmful effect. In rolling-mill operations or in papermaking the changes in sheet-metal or paper thickness cannot be too radical; a very thin material should not immediately follow a very thick material.

LOAD SCHEDULING

Load scheduling is similar to batch scheduling in that attention is directed primarily to the schedule of the batching equipment and little attention is paid to the subsequent operations. The reason is that the goods are processed in the same way and capacity of succeeding stations can always handle the workload. The approach is to avoid controlling other than the key operations, because they run by themselves without special planning and control.

In repetitive job shops as well as in other companies where certain key equipment is the controlling factor, all operations must be paced by the key equipment. Thus, only the time of key equipment is scheduled with care (so that not a minute of production time is lost on it); the other operations may or may not be controlled from a central office. The central scheduling department worries about key machines only, and foremen see to it that the subservient departments that they head absorb the output of the kingpin machine. In other words, foremen of these subservient departments must do their very best to keep up with the output of the expensive machinery. The path is pretty much the same for all products, except that eventually a different operation (and work) is sandwiched in between normal work, the operation time of which vary quite substantially. The task of synchronizing (balancing) work stations with one another is therefore done not scientifically but through good supervision.

Batch and load scheduling can be aided by the departmental load chart described in Chapter 9. The key machines (key departments) are scheduled in the same manner as on the regular machine load chart. The production line or the subservient departments are considered as if they were one single big machine, Fig. 12-4. Care must be exercised that the capacity of the production line or subservient departments is adequate to absorb the output of the batching station or key machines. Minor time variations may be overcome by paying incentives to workers, which might help to balance the time differences. Greater variations in capacity must be balanced by adding to the labor force or by shifting employees from department to department as the need arises.

EQUIPMENT	CAPAÇITY	TIME
KEY MACHINE 1		
KEY MACHINE 2		
THE PRODUCTION LINE		

Fig. 12-4

Block Scheduling

As earlier explained, when the products are different but both the process and the approximate time requirement per operation is the same, or is within tolerable limits, it is advisable to make the products by block scheduling. In this case a group of products follows a certain path that never changes. Accordingly, the product moves from department A to departments B, C, and D in a routine manner. In general, each department knows what must be done and has the skill to do it. This, of course, does not preclude some special information being sent along with the workpieces.

Although this scheduling method is practiced primarily in the garment industry (underwear, sweaters, shirts, and suits) and in the shoe industry, other companies apply it without calling in block scheduling. Builders of motor boats for sport purposes, aircraft manufacturers, and certain electronic appliance makers (primarily the assembly departments) apply this planning technique with considerable success. Despite differences in the goods, the work-in-process moves through the line without interruption.

To illustrate the planning work involved in block control, let us designate departments A, B, C, D, and E through which the block of orders for shirts must move in chronological order. After department A has completed work on block 1, the whole block goes to department B and from there to department C and so on until the whole block has been processed. We have to remember that, despite differences in the products, the time requirements do not vary much, if at all. The shirtmaker would, of course, try to place all white shirts regardless of the customer in one block. Furthermore, he would block all shirts of the same style and size together so far as possible. Once the composition of orders has been established, the block is listed to include, for instance,

2 dozen white	size 15, style A
1 dozen	sleeve length 34
1 dozen	sleeve length 35
3 dozen white	size 15-½, style A
1 dozen	sleeve length 34
1 dozen	sleeve length 35
1 dozen	sleeve length 36

The block, when completed, consists of enough work to keep each department busy for, say, ½ day. This quantity might be called a bundle or a block. Thus, the scheduler works out the schedule for block 1 as shown in Fig. 12-5. The chart shows that block 1 is completed by Wednesday noon, provided it starts on Monday morning. Block 2 is completed Wednesday afternoon; block 3 is completed Thursday morning.

DEPARTMENT	MONDAY		TUESDAY		WEDNESDAY		THURSDAY		FRIDAY	
A	1	2	3							
B		1	2	3						
C			1	2	3					
D				1	2	3				
E					1	2	3			

FIG. 12-5

This scheduling procedure goes on until the time available in the various departments has been allocated among blocks of orders. After this has been done, every one of the many blocks has a definite time schedule like the movement of a train. When the orders should be on any given day is known by the whereabouts of the block in which the order is being manufactured.

It must be obvious that the scheduler does not worry so much about allocating the plant's capacity as he does about determining the block composite. Blocking of orders must be done skillfully in the sense that each block should have just enough work for each department that flow is in predetermined time intervals and is uninterrupted. Often a customer's order may be distributed among several blocks because it is in the interest of production economy that identical items for several customers be pulled together and sent through the plant facilities under one block number. Care must also be taken in the accumulating of orders that the time requirement of the block as a whole does not exceed the established time interval. Block scheduling is good if work flows smoothly from department to department. Yet it must be apparent that it is difficult to have perfect flow because of wide variations in the skills of operators. In the garment industry the skill for stitching operations lies with the individual rather than the machine. The rate of output also tends to vary with the type of shirting that is being stitched.

Although shirt manufacturing has been used as an illustration, the block idea may be applied in different forms to other industries. In some industries each piece in the block must be accompanied by certain papers. These papers identify the block and the order within each block. In addition, if the product variations are substantial, each item might have a number of its own. This may be true in suit fabrication, where a serial number identifies each individual suit, including the customer, the block, and the cutout parts. Pay coupons accompany the bundle, and several bundles[2] make up a block. The coupon sheet is used to identify the bundle throughout the manufacturing process and inform the various operators about the variations which must be built into the product. Accordingly, each piece part will be tagged with a number and each operator receives, via the coupon sheet, a matching set of instruction tags.

DISPATCHING

The general nature of dispatching is substantially the same whether we deal with job shops or repetitive production shops. Thus, most of the work explained in the preceding chapter is also done in repetitive production. Generally speaking, however, dispatching is divided between the production control office and the foreman. The former merely prepares the papers which accompany the product.

To make plans a reality, the necessary material and tools must be made available. In the case of repeat orders, the tools are customarily stored in a toolroom or crib. Broken tools are repaired as soon as practicable, and by the time of a new run the tool shortages have been remedied. Material is usually available because, as explained under the concept of inventory control based on use rate or dollar ceilings, a certain minimum amount of in-process and raw material is always stocked. Nevertheless, the dispatcher always checks whether the necessary materials and tools are actually available.

In steel plants, millwrights must be notified to reset the rolls; in chemical plants, in food processing, and in many other process industries, the containers, vats, tanks, and other holding devices must be cleaned and got ready for a new run of something else; in some other plants, such as those making automobile chassis, the production line must be converted from the setup for a passenger-car chassis to the setup for a truck chassis. In other words, equipment must be converted to other uses, and the time for this conversion may vary from a few hours to a couple of days or more.

When a new run is being scheduled, the whole production line, or at least the batching station involved, must be converted. Changeovers must be accomplished with the least amount of interruption of normal operations. Therefore, the latter are scheduled to coincide with idle time (downtime) and are most likely done during the night. By the time workers return to the first shift, the equipment is ready to go. If this is impossible, the normal work crew is usually trained to do setup work.

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[2] In some companies, a *bundle* is a subsection of a block of orders; otherwise *block* or *bundle* may mean the same thing.

The workers are usually skilled in the production of various items the plant is equipped to turn out, and they can switch from making one thing to making another. Although a generalization may be misleading, the nature of repetitive production may be such that when changes must be taken care of, those who will make the changes are instructed specifically on what to do and how to do it. If batching stations are involved, the schedule and the route sheet must be accompanied by a processing instruction, usually the replica of a master processing instruction. In the chemical industry this will likely consist of a list of ingredients based on a chemical formula. If secret processes are involved, instructions are often given in coded form so that no one except the top administrators know the exact ingredients. The valve settings, gage readings, pressure, and other processing instructions must in such instances also be coded, although most workers may be unaware that this is so. Actually, the coding is done by modifying the gage settings. Even though zero does not really mean zero, the processing instructions will accomplish what they are supposed to and goods will be made in accordance with predetermined processes. In the garment industry, and of course also in certain other types of assembly industries in which the parts are standard but are put together in different ways for different sets of products, it would be inadequate to inform the workers in general, because specific instructions must be given about every change which is required. Here the dispatching function will, among other things, consist of preparation of processing instructions given to the workers in form of detachable coupons which are also used for wage payment purposes. Thus, in batch production, tags must be prepared to accompany each batch. Through the tag system, batches can be distinguished from one another.

In batch control, whereby ingredients might differ at the very first station but the product might thereafter be processed pretty much as any other, tags are of great importance. Otherwise, the wrong material would often be prepared for filling a specific order, and this obviously must always be prevented. The best method is to attach a tag to the container holding the goods in process, or as an alternative, to stamp the name of the customer into the material itself to assure that it is always known what it is and for whom it is intended. Often the serial number might be used as a means of identification. In that case, the tag must give all the instructions relative to a given serial-numbered item either step by step as it is moving down the production line or only for the critical operations.

In the garment, shoe, and certain assembly industries, each product must be accompanied by separate instructions which remain with the product or group of products as it moves. Obviously, it would not be adequate to merely inform the foreman about the differences to be built into the product and expect him to instruct his subordinates, because there are too many little details which must be communicated to various work stations. In some appliance assemblies, for instance, the motors must differ in voltage, type of current, or horsepower; certain attachments must suit the customer's specifications (for example, in waste disposal units, the sink opening may depend on the customer's sink specifications); and the dimensions must vary with capacity and other requirements. By attaching a printed form to the chassis, employees at given work stations can be instructed on the various differences by check marks in appropriate columns or boxes. The detachable coupons serve both as pay and work authorization on the one hand and as a means of control on the other. Here the dispatcher gives direct instructions to the workers rather than to the departmental supervisor. It should be understood, however, that the foreman's authority is by no means affected, because this is a highly impersonal contact between dispatching and employees. It goes without saying that it would be impossible to direct employees otherwise.

That these tags are used in cost accounting and in piece-rate computations is a further advantage of this method. In the assembly industries, the employee is instructed via a check mark on a bill of materials, or the part to be used might also be indicated on a detachable tag rather than by check mark. In that case, the tags are used every day to check against inventory use. When something is being used more frequently than something else, the minimum is also reached more frequently and a replenishment order will be given to the parts-making department. Thus, these tags might be very useful in various functional areas. At this point mention should be made that these tags can also serve the expediting function to be explained later.

After these forms or tags are prepared in duplicate, each is used for different purposes. We shall use the clothing industry as an illustration. The tags are printed with a suit number as well as a part number. Each piece part has appropriate suit and part numbers as well as block and order numbers. Not only will employees in the sewing department (assembly department) know which sleeve and pocket belong to which coat, but the cutting department will not cut more pieces than necessary. In other words, the tag system coordinates the assembly and cutting departments. In this way the plant will have just enough sleeves, pockets, and all other cut piece parts necessary to make the desired number of suits. It would be wasteful to have one or two extra sleeves, whereas in the automobile industry the leftovers might be used as replacement parts.

EXPEDITING

By definition, expediting means a continuous control over progress made against a predetermined plan, and by implication expediting also means action to remove eventual obstacles to production. The primary function of expeditors, then, is to keep track of orders and, in the event of delays, to suggest ways to keep things moving. Just as a delay in a job shop will compound the difficulties, so in repetitive production will a delay cause more and more delays. If, for instance, a product group in block scheduling is delayed in one department, there will, of necessity, be a delay in another department and possibly in a series of dependent departments. It is therefore essential to keep track of the progress of each block. More will be said about this a little later. At this point only the reason for expediting in repetitive production is emphasized.

To some extent, expediting is easier in repetitive production than in the previously discussed intermittent job shop. First of all, the products which move through the production shop pretty much follow the same course. Secondly, there are fewer operations for which specific expediting effort is needed. The fact that the movement of the goods through the line follows a more or less fixed path makes a built-in system of expediting possible in most instances. However, this is not necessarily so. In batch control, for example, each batch of goods moving through the production line must be kept separate from each other batch. This is important because the differences between products might not be apparent, particularly when chemical differences are involved. Systems which preserve the identity of batches are of considerable importance.

Expediting in Product Cycling

When an integrated production process, such as food processing, chemical processing, or rubber preparation is involved and the plant as a whole is converted from one kind of product to another, expediting is mainly concerned with keeping the process in operation. In case of trouble, immediate action is needed to prevent material from being ruined, as it might be in papermaking, by overcuring something or overexposure. The nature of trouble is usually related to some mechanical failure or to the inexperience of the men running the machines. Since a product of the wrong quality might not be acceptable to the customer and valuable production capacity might thereby be lost, technical men such as engineers and chemists rather than expeditors are needed to help the men on the job decide whether the quality of the product is satisfactory and whether the machine can be accelerated to get greater output per hour. Thus, most of the expediting work rests with engineeering or supervisory personnel. When the stockroom requests expediting to have things ready in time, it is up to scheduling to find the necessary time on the machine. If a material is used up faster than anticipated by the prevailing inventory rule, it is conceivable that expediting will, in effect, be done by the inventory control group. Since processing time is usually fixed, either rescheduling or overtime work may be necessary, since a delay in one department is bound to cause a proportionate delay in another one. Thus, to catch up, expediting may mean either rescheduling or the loss of sales.

Expediting in Batch Production

Where batch production is practiced, expediting is restricted to the batching station. As long as the material is processed there and gets into the normal stream of production, further expediting effort is not needed, because some form of product will culminate as a matter of course. It should always be remembered that the rest of the plant operates somewhat like a continuous production line. Mere checking with the batching station whether or not a given batch was started is usually enough to maintain output levels. Control might be exercised by requiring a report from the batching station when a batch is started. If a report is not received, an expediting effort is due.

Expediting in Block Scheduling

In block scheduling expediting is accomplished as a matter of course. As each block passes through a given inspection point, the accumulated inspection tags indicate that fact. Thus, one always knows where the block is, and since each block takes a given amount of time for completion in each department, one knows when a block should be in the finishing department. Checking at certain work stations is merely a precautionary measure to make sure that blocks advance as they are suppose to. A delayed block would hold up completion of any subsequent block. Thus, added help in one department can accelerate production on the laggard block.

Generally speaking, the block control system has built-in expediting in that "pull" and "push" are attained; the foreman in charge of one department has an interest in clearing all units belonging to a block before starting work on the next one. On the other hand, the foreman of the next department is asking for the block because, unless his department starts on the block in time, it is impossible for that department to finish its work in time. It should, however, be clear that real control can be attained only after every second block (if a block represents a half-day's work) has been finished. The reason is that the tail end of the preceding block might still be in the department at the time work begins on the next block.

Expediting in Load Scheduling

Load scheduling, just as that of batching stations, is concerned with a specific or several specific key operations. The production control department is interested in the results of key operations only. In a paper mill, for instance, the multimillion dollar papermaking machine turns out the paper, and how much the finishing departments will do depends entirely on the output of the paper machine. An upset on the key papermaking machine could cause serious delays. Once the scheduled output is attained, as reported at the end of each shift, the subordinate departments will have to absorb the output.

The expediting effort, just as the scheduling effort, is restricted to a few machines rather than to all the machines of the plant. It is evidently important to know whether the key machine has accomplished the assigned work, because in case of delay, the difference must be made up the next day or through overtime work. The other, subordinate departments will usually absorb the output, because the various departmental capacities are gaged to the key machines. When trouble is anticipated, supervisory personnel are instructed to report probable delays, because the output of several related departments must be adjusted sufficiently ahead of time to prevent departments from being left empty-handed. In other words, if the key department falls short on its output or is not turning out goods at the predetermined rate, all subordinate departments are idled. Other arrangements to keep the men and the machines in operation are very difficult because of the lack of availability of basic materials. A quick reschedule—to work on something which would have to be done anyway, but later—might remedy the situation temporarily until finally one succeeds in raising output on the key machine.

THE SUPERVISOR'S ROLE

In repetitive-type operations, the supervisors perform a great deal of the production control work. At the same time, a great deal of the engineering work is done by production control. The fact is that everything is routine to the employees, and supervision—in the sense of constant instruction giving, training on the job, and disciplining—is less complicated than it would be in an ordinary job shop. Thus, some of the planning work rests with the supervisor.

To be specific, when product cycling is involved, the supervisor merely has to know which product must be run next to know what to do to get the department ready for the next job without receiving elaborate processing instructions. He knows precisely the preparatory work involved. In block control, he merely has to see to it that material is obtained from the preceding department and learn about the type of variations on the various orders constituting the block. In batch and load controls, a foreman in a subordinate department must plan work to have everything scheduled so that the output of the key machines is fully absorbed. No schedule is determined for him, and it is up to his planning skill and effort to keep operations moving.

SUMMARY

The Economic Necessity of Becoming a Repetitive Producer

Since the aim of every industrial enterprise is to operate at the lowest possible cost, industrial enterprises do everything in their power to reduce the costs of production, including those of storage. From the point of view of low-cost operations, the best thing would be to operate continuously and produce one product only. By running the equipment at or near 100% of capacity, the overhead cost would be reduced by distributing the fixed expenses among the largest possible number of output units. But there are several reasons why companies cannot do this. The main reason might be that consumer demand fluctuates both seasonally and cyclically. Hence, the production of uniform quantities is difficult, because the cost of storing the surplus might be greater than the savings effectuated by the production on a continuous basis. Another reason might be that at times it would cost almost as much to build a plant with a capacity of 100 units per day as 500 units per day. Every company will therefore build the largest plant it can for the same money. The only trouble is that we now have a plant considerably greater than consumer demand warrants.

Only two reasons have been given, but there are many other reasons why a company cannot operate continuously. All the problems boil down to this: demand does not warrant continuous production; raw materials are available only seasonally; and the unit cost considerations versus setup and storage costs are more favorable to repetitive production techniques than to continuous ones. Consequently, when the facts of economic life necessitate repetitive rather than continuous production, company engineers and production control men will devise a system which permits operations commonly referred to as repetitive production.

The repetitive producer uses economic lots to allocate the production capacity of his equipment to different uses. Longer than economic runs would mean undesirably high storage cost of the surplus kept in stock. Therefore, a careful calculation is made to determine the size of the lot.

The plant capacity is then parceled out to the various items. Evidently, there must be a great degree of similarity so far as the production process is concerned, even though the products might be quite different. A cannery might produce canned carrots and marmalade with the same equipment. Although the products are entirely different, the production process may remain pretty much the same.

At times, special plant layout arrangements must be devised to make the production of several products possible by using the same production line or production facilities. Chapter 8 not only gave some explanatory material on how this can be done, but case studies illustrate this possibility in certain industrial enterprises. In some other instances, the production process is identical for every product, but the sizes, styles, and dimensions of the various products can be different. While the production flow will be continuous, or nearly so, it is essential to make certain that employees performing the various operations on the production line do not confuse sizes, widths, colors, and the many other differences involved in the various items produced on the same production line. Bathing suits, shirts, suits, and shoes are manufactured in this manner. Here it is up to the production control department to devise a paper-work system which informs employees what to do to the various products moving along the production line and also a production planning system which will combine orders of several customers and allocate plant capacity in an orderly fashion.

The production control techniques will differ, but their aim is to create a "relatively" continuous flow of production even though the nature of production would ordinarily permit only job shop operations. Somebody said that repetitive production is more or less a "glorified job shop operation, but one which approaches the cost structure of mass production."

Production Flow Through Ingenuity

A great deal of ingenuity is necessary to create continuous production flow in job shop operations. Although it is difficult to classify the various hybrid production techniques which have been developed to control the flow of operations in repetitive production, some of them have been given names. Hence, there are batch, block, bundle, and parts control systems. These are specific methods used in planning the flow of orders or lots through the plant. The system enables the planner to check on the progress of each order or lot and to apportion plant capacity according to a system which permits low-cost operations.

Advantages of Repetitive Production

It is rather complicated to develop a repetitive production system. To begin with, certain prerequisites are necessary. There should be a large enough volume per year to warrant it, but, particularly, the sum total of all units produced with the same facilities should add up or be close to the plant capacity. If the capacity of the plant is not sufficiently utilized, operations per unit might be too costly. For this reason, prior to building the plant, it is essential to familiarize oneself with demand conditions and the probable sales volumes from each product, the seasonality of each complementary product, and the overall fixed costs versus the sales volume.

The main advantages of such a plant are flexibility and the capacity to adjust to changing demand conditions without too much trouble. The problem of what should be produced at any given time is easily answered through the inventory control procedure which indicates the minimum point at which the production of an item must be scheduled. Thus, the plant will be converted to the production of that item. Care must always be taken that inventory accumulation is kept at a minimum and that unit costs are compatible with company price policies.

QUESTIONS

12-1. How and in what manner is repetitive production similar to job shop operations as well as continuous mass production?

12-2. What kind of a plant layout arrangement is there in repetitive production?

12-3. How would you classify the goods which are certain to be produced with repetitive production techniques?

12-4. What characterizes most repetitive operations?

12-5. Can you describe a few companies which are certain to operate with repetitive production techniques?

12-6. What is block control?

12-7. What is batch control?

12-8. What is bundle control?

12-9. Why are economic lot quantities so important in repetitive-type operations?

12-10. Is there a relationship between inventory control, economic lot quantities, and production control in repetitive type operations? If so, what is it?

12-11. How are economic lots calculated?

12-12. What role does the sales forecast play in repetitive operations?

12-13. What determines the content of a production *block* in block control?

12-14. How is the route of a *batch* planned and carried through the various operations?

12-15. Departmental work load charts and inventory control charts are used in repetitive production as planning tools. What information do these charts convey for the production planner in repetitive-type operations?

12-16. How does the repetitive producer keep track of parts used by the production department at different rates on the various items produced?

12-17. What system is used in repetitive production to replenish inventory levels?

12-18. What is the usual minimum inventory level?

12-19. How is the maximum inventory position calculated?

12-20. How does the repetitive producer keep track of minor differences between otherwise identical products such as shirts?

12-21. What is the nature of routing in repetitive production?

12-22. What, in a highly generalized sense, is the nature of scheduling in repetitive production?

12-23. What is the function, if any, of the dispatcher in repetitive operations?

12-24. Is expediting a necessary function in repetitive operations? Explain.

12-25. How does the supervisory function compare in repetitive production with a) job shop foremanship and b) foremanship in continuous operations?

12-26. What makes companies become repetitive instead of intermittent or continuous producers?

PROJECTS

12-1. A well-known canning company is engaged in the production of fruits, vegetables of all sorts, soups, and vegetable pastes. To produce all of these the company uses the same production facilities. The peeling room consists mainly of benches along which women peel the tomatoes or arrange the string beans so that the cutting machine can cut them in appropriate sizes, or do any other types of work associated with the initial cleaning operation. The size of the work force varies with the nature of the cleaning job. This is a seasonal job, and the people who are engaged in it periodically return to the company.

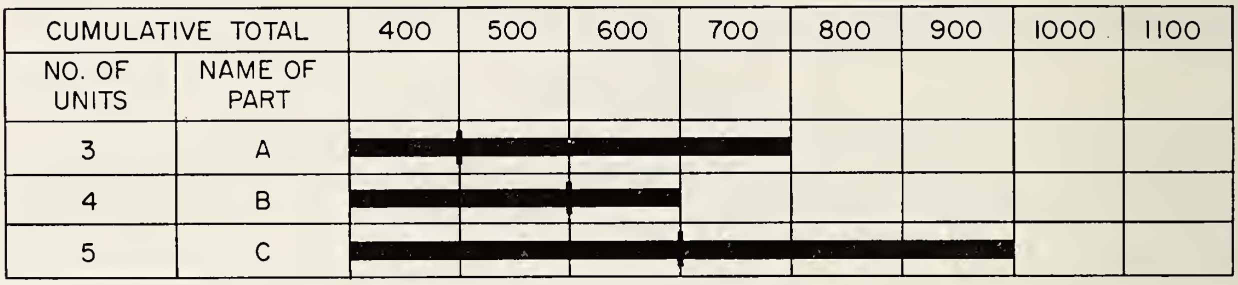
The rest of the operations are rather standardized production processes. With minor variations the products move from one tank to another through pipelines. Although the cleaning process varies and cooking time must be adjusted, one can generalize and say that on the average the company produces each item for 10 days, excluding Saturdays and Sundays. Pork and beans is a fill-in item and is produced when the machines have nothing else to do. Once a 10-day period is over, the machines are cleaned and prepared for different uses. The company tries to do this on weekends, since only eight maintenance men are involved and their schedules are such that they have their days off during the week rather than over the weekend.

If you were the production scheduler, how would you arrange production on a yearly basis so that each item was produced for 10 days to coincide with a seasonal raw material supply but the downtime was kept at a minimum? In other words, the task is to setup a production schedule which will permit a relatively continuous utilization of plant facilities.

Occasionally, but not often, the 10-day production schedule of a given item is reduced to 7 or 8 days or raised to 12 or 13. Obviously, if the inventory position is unusually high when the new batch of the item is to be made, the production department reconsiders the production volume in light of the inventory position.

Divide the year in 10-day periods and set up a schedule for the plant (list the items you would produce in given seasons). To do this, check on the seasonality of various items. Evidently, when the price of the raw material is the lowest, the production will be scheduled. There are, of course, overlapping periods when extra care must be taken.

12-2. The inventory control chart of a company is reproduced in the accompanying illustration. State how many pieces of parts A, B, and C are still available. Also indicate how many completed units can still be produced if all finished units are composed of parts A, B, and C.



Minimum quantities or reorder points are indicated through a line intercepting the available quantity line.

12-3. According to Raymond's fundamental model of economic lot quantity:

$$\text{economic lot} = \sqrt{\frac{P \cdot F \cdot Sa_s}{(K_s + K_w) \cdot fr + K'_v}}$$

Determine the meaning of symbols in the formula by assuming that the economic lot quantity represents the quantity such that the costs of production and the inventory carrying charges are at their lowest levels.

12-4. Explain the value of economic lot calculations in respect to determining how much should be produced if and when it is decided that a given item is to be produced.

12-5. Determine the importance of production control work in repetitive-type production as compared with intermittent production.

CASES

12-1. Tropical Shirts Incorporated (Part 3)

In view of the severe competition in the shirt business, TSI has considered every possibility of cost reduction in recent years. Currently, within the framework of modernization, an effective production control and plant layout system is also contemplated. It should be remarked, however, that the quandary in which the company now finds itself has resulted from an attempt at cost reduction just a few months before. This system must control the flow of production from the cotton cloth stage until the shirt is completed, pressed, and packaged.

The plant of the TSI is located on the outskirts of Los Angeles, California, and the company specializes in the manufacture of summer sport shirts under the tradename of "Tropical Shirt."

Originally the company operated under the bundle system and prospered, but with the constantly rising labor costs and inflationary tendencies on the one hand and price competition on the other, the spread between costs and prices started to narrow to such a point that, in order to break even, quality had to be cut. The company seems to have exploited all the possibilities offered by this kind of speed-up. A further problem was the wide fluctuation of output by employees under the bundle system. Each employee had to learn how to sew a large number of different seams, and the frequent quits among workers, usually girls between 18 and 25, caused the loss of the better workers whose output was often 70% higher than that of a beginner. Thus, to simplify work, the assembly department was set up on a production-line basis and the other departments remained as they were under the bundle system.

Let us review the system which was in practice in the past to see the nature of changes which were undertaken. The bundle represented the control unit of identical shirts as to size, style, and color. One trouble with this system was that employees had to know too many different operations; another trouble was that large sums of money had to be tied up in idle inventory at any given time.

Under the bundle system, production was scheduled on the basis of 1) stock replenishment orders and 2) new style orders. In the first instance, the stock clerks were instructed to write out the size, style, and other features of a given shirt group which ran low. Anything below 2 dozen was considered below the desirable minimum. At this time, the item was written on a sheet of paper called "inventory short list." If replenishment was decided upon, the order called for a new bundle, 10 dozen shirts. Thus, the very maximum number of shirts in stock would be 12 dozen.

The clerk merely made up the short list, but whether a production order was given depended on the approval of the manager. The manager always checked when the last bundle was made (the date was also written on the short list); and if it took longer than 4 weeks to sell a given bundle, the style and size was discontinued on the ground of odd size or undesirable style. Whether an item would be replaced was sometimes a borderline question which the manager decided.

By using the bundle system, the company was always ahead of its competitors so far as style and smartness were concerned. In addition to the old styles on the short list, new styles were always being added. Some old styles were dropped, which does not imply permanent discontinuation because customer tastes often changed and an unpopular style could become very popular at a later time. Certain styles were designed or rescheduled on the recommendation of sales personnel who, being in the field, were informed by distributors about the popularity of certain competing styles. Pirating (copying the styles of others) is an accepted practice in the garment industry, and if another company puts something on the market which seems to catch the fancy of the buying public, it is only good business to copy it. Within a couple of days, Tropical Shirts Incorporated could place any kind of shirt on the market, although perhaps not in every size. Generally speaking, TSI believed that everybody else copied their design rather than the other way around.

Of course, items could be scheduled in order of importance or in the order of need. Either way, when plant capacity was available, the order to be produced was scheduled. Schedules were sometimes planned 10 weeks earlier and dispatched only a day before actual operations were to start. Dispatching was primarily accomplished by releasing the cutting scales (see the accompanying illustration). This authorized production of not only a bundle but also that of the material needed, including the findings (labels, boxes, buttons, threads and linings).

Recently, when the company ended a year with a substantial loss, company management decided to convert the process layout to a line layout. The parts still went from one department to the next, but the assembly was based on continuous flow and the garment went from operator to operator. The time study which was needed to balance departmental capacities with one another and with the various operations on the production line was made by a local consulting firm.

The system was excellent in terms of production efficiency, and the plant could have operated at extremely low unit cost had sales been large enough to use the plant's output capacity. But sales were declining instead of increasing. The new system both cut cost per shirt and increased quality, but the fact of the matter was that the company so far had not really benefited from the savings.

Savings were not realized because certain unforeseen problems arose. At first it appeared that a seasonal decline had taken place. Soon after, however, it became apparent that the marketing outlets were severely reducing their orders from Tropical Shirts. Upon panicky inquiries, the opinion gained acceptance that in the standardized shirt business, TSI had very little chance of succeeding. With strictly staple goods, TSI was just one of the many shirt companies. The company's competitive advantage used to lie in large variety, originality, and style. Thus, despite cost reduction, overall profitability regressed rather than progressed. The savings were offset by the storage costs and carrying charges on idle inventory items.

During a policy meeting, the matter of profit versus operating efficiency

CUTTING SCALE CS 11 1

CUTTING SCALE WEEK OF 8-6-62 SALE Fall 62 Oct.

LOT NO. 6778	STYLE 2497 MITOGA CONTOUR TABBER SNAP U. F.		DOZENS 147
CUTTER	DATE CUT	PIECED SLV.	MATERIAL Gordon Oxford Blue
YARD SLIP NO.	MADE AT 610 Troy		
FRONT STAMPING PATENT NO.	SIZE & CC SANFORIZED MADE IN U.S.A.		

UPPER 857 ch UNDER 858 ch	COLLAR TOP 359	COLLAR TOP F	COLLAR TOP B
POCKET 1-1929z	COLLAR BAND 215	COLLAR BAND F	COLLAR BAND B
UPPER FT. centerpleat FAC. 3104	CUFF 374	CUFF F	CUFF B
UNDER FT. FAC.	SLV. AND SPL'T 872	COLLAR TOP L 375	COLLAR BAND L 375
BACK 859 ch	SLV. CLOSURE 483	CUFF LINING 285	LABEL NO. 104
BACK PATCH	YOKE 860	CUFF BUTTON 1/dd/17	SPECIAL LABEL NO.
INSERT NO. 29 PS	TRIM BLOCK NO. 215	FRONT BUTTON 5/dd/17	BAND DRESSING none
TURN POINT DIE NO. 359	TRIM TEMP. NO. 359	COLLAR BUTTON 1/dd/15	PACK 4/12
TOP STITCH STEAM 5/32"	tabs 345	COL. PT. col.bk.bh. BUTTON & 1/dd/14	BAG NO. 202

REMARKS

GRIPPER FASTENERS ON COLLAR TABS

TOTAL DOZEN		1	22	36	54	28	6				147	
	13½	14	14½	15	15½	16	16½	17	17½	18	TOTAL DOZEN	BODY LENGTH
SHORT SLEEVE												
31												A
32			13	14	14	3						
33		1	9	15	20	10	5					B
34				7	14	10	1					
35					6	5						
36												C
CUFF DIV.	F		G		H		J		K			
TOTAL DOZEN	1		58		82		6					

Cutting scale used for giving cutting and manufacturing instructions to the factory. (Courtesy of Arrow Company, a division of Cluett, Peabody and Co., Inc.)

was debated. Mr. Goldfinger, the general manager, claimed that the recent conversion from the bundle system to the line system of production had brought about 50% reduction in labor time, permitting a widening in profit margin. "Indeed on what we have sold," he claimed, "profits were highly satisfactory. The trouble is that many more shirts were produced than sold. And sales are now our problem. Our sales people are evidently accustomed to selling variety goods, and they just do not know how to sell standardized staple goods. In my opinion a training program would likely cure the situation. I propose therefore that every one of our salesmen participate in a 4-week retraining program to be held 3 times a week in our downtown office."

The sales manager claimed, however, that because of the great difficulty in selling, sales expenses relative to sales volume had also doubled in recent weeks. Simultaneously, it was becoming extremely difficult to retain the services of even the veteran salesmen, some of whom had been with the company since its inception. The sales manager foresaw a serious turnover in sales personnel and forecast a further rise in sales expenses per unit of output unless the company returned to the production of a wide variety of style goods to which Tropical Shirts customers were so accustomed. However, salesmen, in light of what Mr. Goldfinger said, admitted that it was a new experience to sell standardized shirts and that it was "murder" to sell against formidable competition in staple goods.

According to a recent report of the treasurer, too much money is being "shelved," as a result of large accumulation of unsold merchandise. The interest paid on borrowed capital has jumped from a monthly $400 dollars to $600. Whereas in the past it was assumed foolish to spend substantial amounts of carrying charges (including interest) on finished inventories, now it became clear that the situation was worse than it was ever before. The company would certainly be in the red again unless something drastic was done about production and sales, and primarily sales.

A week after the conference, company officials felt that in order to reduce inventories, operations had to be suspended until at least 50% of the current stock was depleted. Sales personnel were instructed to make a strenuous effort to put all shirts then in stock on the market. Repainting of the plant would be used as the excuse for the layoff as far as the production departments are concerned.

It was hoped that operations could be resumed within a month. Based on the contemplated shutdown for a short period of time, operations would not be seriously affected in the future. Overhead costs would, of course, continue to weigh heavily on the company's cost structure, but out-of-pocket costs would be conserved.

Haskell-David-Ferguson and Associates, a local consulting house which helped set up the production-line technique for the assembly department, was consulted immediately when the trouble became serious. While the firm did not advise Tropical Shirts Incorporated to adapt the production-line technique, it performed the time study necessary to do so.

Since it was apparent that TSI's competitive advantage lay in the "new look," and "variety," the consultants had a system in mind which would be able to keep operations nearly as efficient as under the line system of production but build into the plant operations some degree of versatility to make the production of style goods and variety of styles possible. In addition, it was essential to design a system which would permit minor variations in the sewing room as well. The objective was to make different sleeve lengths, neck sizes, chest sizes, and the many other variations which might be required by the consuming public. In the past only sport shirts with simple design had been made; now, the company hoped to continue making other more complicated models along with the simple design of the traditional Tropical Shirts.

The system finally agreed upon was called block control. Under this system, products did not move one bundle by one bundle to departments, but the whole block was transported to the next department. Within each block, there were bundles of shirts, and each bundle had certain style, size, and other appropriate identification. A prepared pay coupon sheet was attached to the bundle. Although the pay coupon sheet was important to the payroll department, it was more important to production control and the worker because the coupon sheet identified the bundles throughout the manufacturing process. An operator who worked on a specific operation on the bundle in question tore a coupon from the sheet. The coupon was so prepared that it indicated the bundle and the bundle specifications. The coupon sheet had a separate coupon for each operation. That the coupon was then pasted on the operator's time card and was used by the payroll department to figure out the operator's pay is incidental to our present discussion.

The products moved from the cutting, parts, assembly, inspection, laundry, and boxing departments at a predetermined rate twice a day. The output quantities per department were just about equal, give or take a few minutes due to variation in operator efficiency. It was something like a production-line adaptation to the variety requirement. To be specific, the number of employees had to be raised to retain simplified operations, but only as many girls were placed in a department as were required for a given output. All departments were equal in capacity; and where more work was involved, proportionately as many more girls were working. Thus, machines and operators were gaged so that departmental capacities were just about balanced.

One half day's production had to be produced in each department. That a half day's output in fancy shirts would have taken longer than in staple shirts was no problem because, according to the time study, fewer shirts constituted a block in the former than in the latter. How many shirt parts must be cut would be determined in advance and conveyed to the cutters via the coupon sheets. Each bundle had to have its own coupon sheet, and each block was nothing else than the number of bundles which could be turned out in a half day. It is important to remember that a great deal of office work was involved in planning the composition of bundles, the number of bundles in the block, and the information on the coupon sheet. Special attention had to be paid to sizes, and careful measurements had to be made throughout the production process so that the size was indeed as marked. The marking served both the processing departments and the market.

Parts were accumulated in bins before moving to assembly, and shades were paired so that the employee could reach for a given part without much thought. As many parts of a given type were always in the bins as shirts of a given size and type were to be made. Thus, by carefully controlling the cutting operation and the pairing and arranging of parts, thinking was reduced to a minimum. Fancy material is pinned so that the patterns will be aligned on the finished parts. Furthermore, the parts are marked with an awl to aid the operator in positioning the cloth for sewing. Thus, for instance, in plain shirtings, the pocket is aligned with the three awl marks and is stitched down. In fancy shirtings, the pocket is lined up with the two top marks and the pattern is matched with the body and then stitched down.

The inventory department will go back to the old system of putting shirts on the *short list* when they reach a predetermined minimum. However, both the minimum and the maximum will be reduced, because under the system of bundle identification and job communication (via the pay sheet coupons) employees will be able to handle differences without much difficulty. As a result, variety will be maintained at previous levels, yet operations will cause less complication than in the past. At the same time, inventory levels can be kept at a fraction of the cost previously encountered.

The problem of production control will be considerably more difficult than in the past because everything must be thought out first and information must be put down on paper. Time standards on given operations and sizes must be carefully considered so that the blocks will consist of exactly one half day's work. But supervision will in turn be considerably less difficult because the foreladies won't have to worry so much about instructing workers what to do and can handle the personal problems, the personality clashes, and human relations problems in general which tend to arise in an employee environment. Otherwise, by merely releasing the cutting scales, production is initiated and authorized. Inventory control will have a great deal of freedom, because they will, ipso facto, be the ones which determine the production orders. The production control department must merely organize the orders for inventory replenishment or new styles to make up a block. Subsequently, the date when the block should be started must be set. The finishing date is unimportant because, when the cutting scales are released and operations start, production will be finished several days later. Delays are almost impossible because each department can finish work on a block in a half day. Of course, it is the task of the forelady to make sure that employees perform as required. However, the piece rate system of wage payment aids greatly in keeping employees on their toes. Of course, the system as described would not work if time studies were not available.

Employee performances will not vary as much in the future as under the original bundle system because employees will have only a few simple tasks and the time discrepancy is bound to be correspondingly smaller. Since the time standard is based on normal performance, the chances are that the output of the superior employee will just about compensate for the below-normal performance of the beginner.

Since the company is returning to the variety and style type of shirt making, it is assumed that sales will return to normal and it is hoped that when price concessions become necessary to widen the market, the company will be in a better position to make them than in the past.

Questions. The student should notice that the case deals with a style good, yet with a product which can be manufactured with large-scale methods. The bundle system is too expensive; the line system when the product is highly standardized permits low-cost operations but causes difficulty as far as marketing is concerned; the line system which produces all the variety required by the consuming public is cheap from the point of view of production cost but creates costs for a separate production control department. In other words, for one reason or another, something is wrong with all three methods described in the case. Therefore, it is up to the student to discover what is wrong with each of these methods and recommend improvements on any one of the three production systems. If none of these systems can be adapted to this kind of production, the student should devise a system of production planning and control which, in his opinion, would suit the special needs of this company.

1. List the symptoms, if any, indicating that, in the production of sport shirts, a) the bundle system of production planning and control is unsuited, b) the assembly line system, combined with product standardization, is unsuited, and c) the eventually established balanced departmental system adapted to accommodate variations in styles and models is unsuited. If you say that the symptoms indicate something other than suitability or unsuitability, state what the symptoms in your opinion do indicate.

2. Without leaving the question of what is symptomatically wrong with this company, state the factors which tend to indicate that the introduction of the line system has been associated with some pitfalls (necessary concomitants of lack of proper adaptability).

3. No specific system is perfectly suitable for any given company without adjustment to the specific needs of the company and the circumstances in which it operates. What factors did the company fail to consider when adapted to the production-line system; that is, what are the causes of the previously mentioned symptoms?

4. Design a system of production control which would permit large-scale production (and economies of large-scale production) yet enable the company to maintain style, originality, and quality required to make the sale as far as Tropical Shirts are concerned, that is, eliminate all the causes which make the present system unworkable.

5. How does your system compare with the one developed by Haskell-David-Ferguson and Associates?

6. Do you agree with Mr. Goldfinger that the problem lies not in production but in the fact that the sales personnel do not know how to sell a new type of product?

7. In line with the reasoning used by Mr. Goldfinger, do you think that a sales training program would solve the sales problem and thereby solve the production problem also?

8. The problem that too much capital is tied up in unmoving shirts came up twice in 3 months. How, if at all, would solving the production problem also solve the inventory problem?

12-2. THE FRIT DIVISION, FERRO CORPORATION

Ferro Corporation's Frit Division, located in Cleveland, Ohio, is engaged in the production of a comprehensive line of porcelain enamel frits used in the appliance, building, and floor and wall covering industries and as a rust-protective and beautifying agent on many products both of the consumer's and producer's goods variety. Frit Division's porcelain enamel, a glass coating applied primarily to metals, is also made in form of a ceramic glaze used for coating dinnerwares and all sorts of other sanitary wares in the consumer products field. The general usefulness of enamel is evidenced by the fact that it is hard to imagine today's refrigerators, washing machines, pots and pans, china wares, and thousands of other household and industrial items without an easily washable rust-protective enamel coating.

Frit Division accepts orders for small or large quantities of enamel frit with the understanding that the frit will meet chemical characteristics specified by customers, assuming the proper application of the enamel (including the smelted-in colors) on different grades of steel or aluminum. The production of colors, clays, and other binding agents is also carried on in the same plant, but in another division; but those considerations are precluded here. It is worthwhile, however, to point out that the company's Cleveland plant is also engaged in the production of a complete line of color oxides, along with the production of porcelain enamel frits. The enamel frit, mixed with the appropriate color oxide, is ultimately the Ferro product which is used in industry.

The vitreous porcelain enamel sold by Ferro Corporation represents an estimated 45% of United States consumption and 75% of foreign consumption. The company's customers are manufacturers rather than ultimate consumers. Thus, companies manufacturing refrigerators and appliances are the ones who order stock items or a specific mix of frit, including the coloring agent. While stock items can be shipped immediately, frit of special chemical make-up must first be produced. The latter is scheduled for production as soon as the needed equipment becomes free. The shipment has to adhere to both the customer's delivery date and quality requirements. At times delays are forced upon the company because more orders have been accepted than there are facilities capable of handling them. Thus in order to meet shipment, it is not infrequent that Saturday work, at a 50% higher labor cost, and Sunday work, at double labor cost, is instituted. Since labor cost does not represent the largest portion of the total cost of production, in the past the company has not paid its utmost attention to this cost factor. During the recession of 1960, however, when profit margins were paper thin, company management realized that it was essential to pay more careful attention to this particular cost factor. The success of Frit Division depended, however, largely on prompt shipment of orders, and for this reason management was at times willing to pay the price of maintaining its reputation as a reliable supplier.

The Frit Division always showed profits but, in the considered opinion of production management, greater profits could be achieved by better scheduling of orders on the one hand and by establishing a better inventory policy on the other. This proposition, however, involved a considerable amount of difficulty in view of the large variety of enamel frit ordered by customers from Ferro; furthermore, because of the irregularity of orders for relatively small volume (pounds) at a time, it was difficult to get a good mileage out of a "heat." Small orders, coupled with irregular frequency of orders, caused substantially higher unit costs (cost per pound) than would have been attainable had the flow of production not been interrupted. Owing to frequent interruptions in the production flow to accommodate a specific mix, plant capacity was in a sense reduced, and this caused delays in shipments. Obviously, the predicament in which the company found itself necessitated serious investigation leading to a method capable of attaining nearly 100% utilization of capacity and corollary cost reduction in both the overhead and labor sectors, but without adversely affecting customer satisfaction as far as deliveries and frit quality were concerned.

Scheduling was evidently not a simple problem, considering the fact that Ferro-produced enamel glass coating had to conform to certain desired chemical characteristics closely related to the purpose at hand. Because of wide differences in specifications as to the chemical make-up, customer orders could seldom be lumped together to form either a larger batch or a larger run depending on the equipment (small or large ovens). Because the metal or other raw material used by customers varied, the glass enamel had to vary also. That is, the chemical composition and physical properties of the enamel had to conform to the chemical characteristics and surface properties of the metal to be coated. To understand the difficulty resulting from a demand for a large variety of enamel, it might be worthwhile to learn what customers do with the enamel.

There are basically two enameling processes. 1) The wet process, and 2) the dry process, used on heavy cast-iron pieces. In the latter process the metal is heated and finely powdered glass enamel is dusted on it. The heat in the iron starts the fusion, which is subsequently completed in a high-temperature furnace. In the wet process, the glass is mixed with water, binding agent, coloring agent, and other ingredients, applied much as ordinary house paint would be, and then fired to fuse the enamel to the metal. Usually two coats are applied. Of course, to make the metal receptive to enameling, it must first be dipped in a cleaner tank to remove grease or other foreign elements. Subsequently, the metal must be rinsed, placed in acid, rinsed again, then dipped in nickel solution, then in a neutralizer, etc., until finally it becomes receptive to enamel coating. This is an oversimplified version, but the description is good enough for the present purpose. When the metal so treated is finished, it has the refrigerator's white, pink, or other color so familiar to us.

When an order is obtained, production control checks whether it is an inventory item. If so, shipment can be made immediately; otherwise, production must be scheduled. Since most items follow the same production process, except that an additional operation must occasionally be performed, no other complicating factor enters the scheduling procedure. Scheduling consists primarily of allocating available smelter time among different customer orders. The company has a large number of continuous smelters and batch-production smelters. The scheduler's task, according to the diagram, is to assign the smelter time to specific orders, along with all other auxiliary equipment. Smelters operate 24 hours per day. If an order becomes active, the scheduler calculates the time required to complete the order in question and blocks out the equipment for that use as shown in Fig. 1. The production capacity of the smelter is roughly 1000 pounds per hour. An order for 6000 pounds therefore requires 6 hours. In view of the notoriously small order quantities for chemically identical frits, the next order cannot be assigned in immediate succession, because the changeover from one use of the smelter to another precipitates approximately 3 hours of loss in otherwise available capacity. Thus, the next order can be scheduled beginning with the ninth productive hour. On the assumption of three orders of identical size, the loss in daily capacity amounts to from 6 to 9 hours. Thus, the maximum capacity is in reality 18 hours instead of 24 hours. The smaller the order size and the larger number

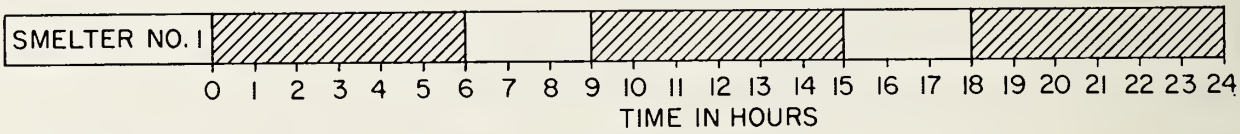


FIG. 1

of orders which are sent through the smelter per day, the greater is the shrinkage of capacity.

Of course, the 3 hours spent on changeover is not always a complete loss, because the wash-out material used to clean the smelter can occasionally be reused in the same manner that scrap iron is used in steel production. Nevertheless, approximately 2000 pounds of enamel mix, sent through the smelter for cleaning purposes, might not always be commercially disposable. Since valuable raw materials are involved, "rinse production," deserves further study as a cost factor.

Production scheduling also implies the scheduling of all related operations, (see Fig. 2), namely

1. Weighing out the ingredient raw materials.
2. Mixing these raw materials (special care must be exercised that the *mixing time* is just right; a homogeneous mix is of considerable importance in maintaining uniform melting and glass properties.
3. Check-weighing; really an inspection operation to assure the propriety of the mix. Unless the mix is composed of the right amount of each ingredient, the resulting glass frit might turn out to be qualitatively inferior. For this reason, the total mix is now weighed to make certain that the "whole is equal to the sum of its parts."
4. Smelting; the mix is sent to either the continuous smelter or to the batch smelter depending on production volume.
5. Cooling; the enamel frit is reduced from the fluid red-hot form to a solid state by either air or water cooling. Which method is used depends primarily on the customer's requirement and on whether the smelting process is continuous or batch.
6. Packaging and weighing, usually in 100-pound bags. This operation is inherently connected with cooling in continuous-production smelters.

Nevertheless, by scheduling the key machine (the smelter), all other operations can be made to fall in line. This kind of scheduling is called load control. The flow diagram for a typical plant using continuous smelters is shown in Fig. 3.

At the weighing operation care must be taken in calculating loss factors before and after smelting. For this reason most calculations take the possibility of material evaporation into consideration. The calculations are made on the basis of 100% yield in glass equivalent (oxides and fluorides as determined by the chemical analysis). The raw materials in question are essentially inorganic oxides, minerals, fluorides, or salts. Oxidation is required during melting of the glass at varying degree of heat conditions. Oxidization is precipitated through the use of some proportion of nitrates in the composition. The ingredients, granular or powder, must suit the equipment and chemical requirements. For ease of dumping all ingredients together, a movable car passes underneath the material storage bins. As the car stops under the hoppers, it

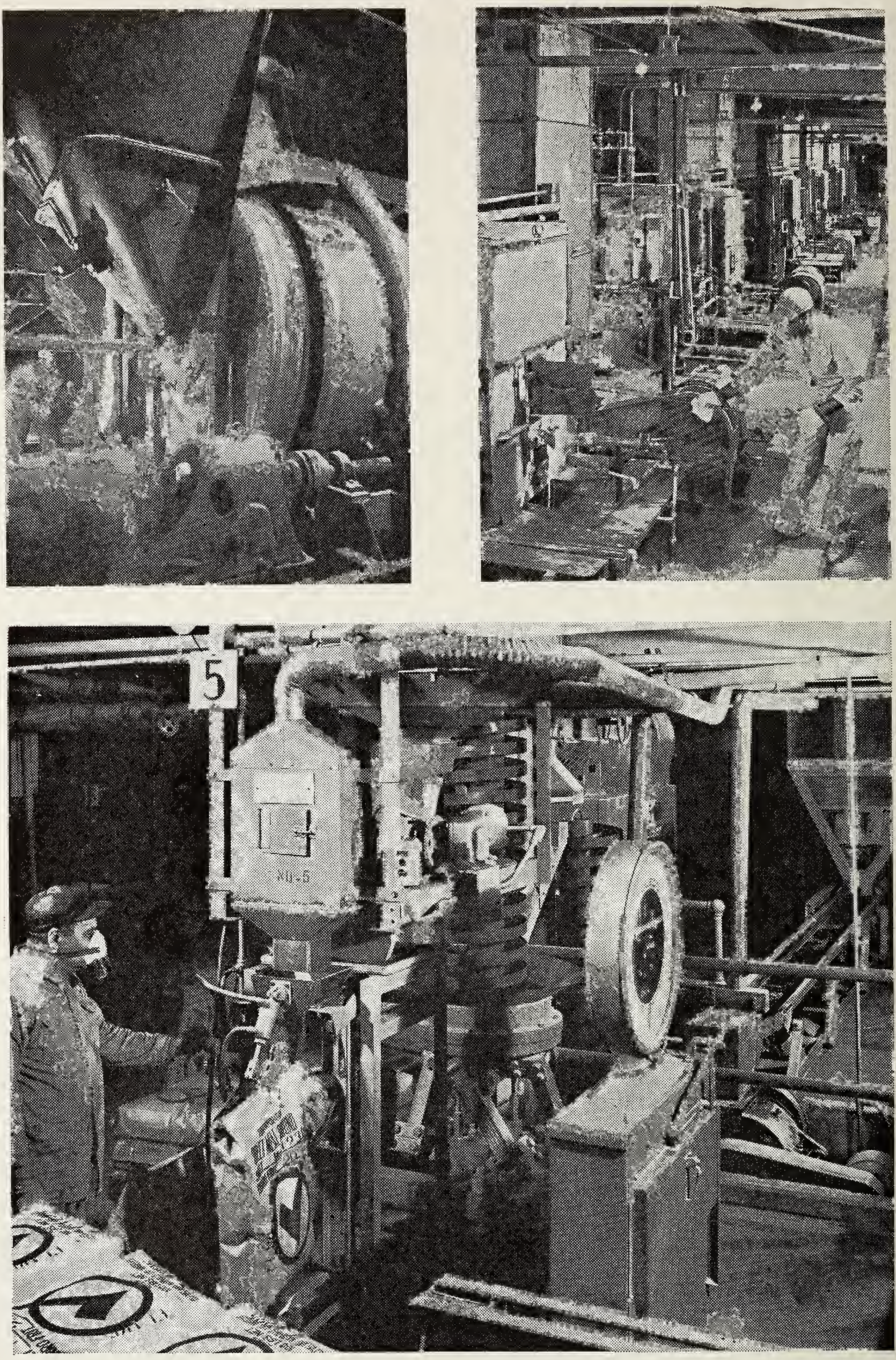


FIG. 2. Some of the operations in production of frit. (Courtesy of Ferro Corp.)

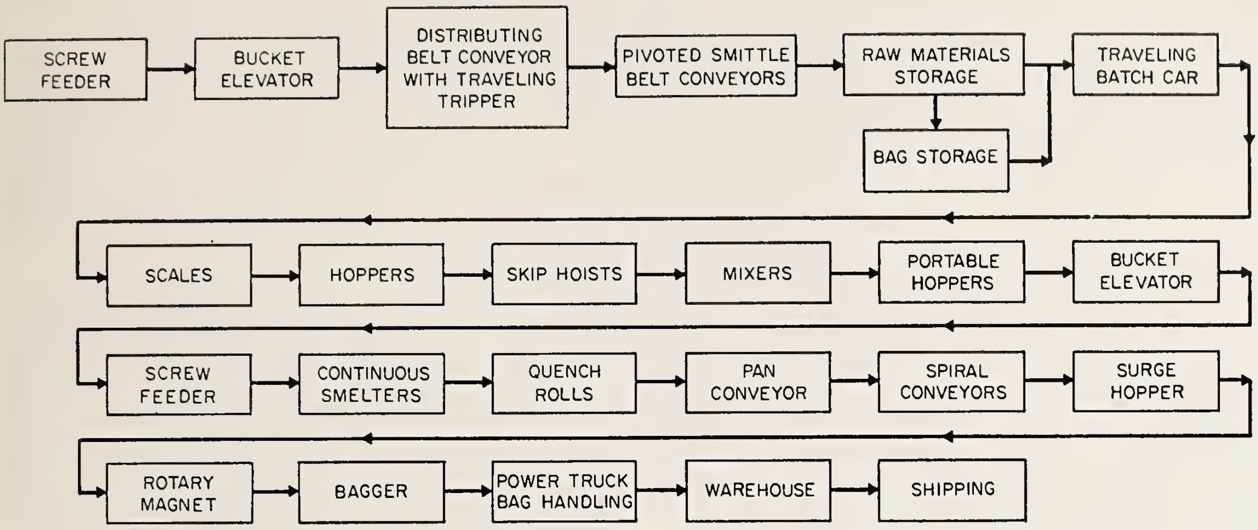


FIG. 3

gradually accumulates all the chemical components. The ingredients are given in percentages of the total, so that the melted product will be equal to 100%. The chemical composites might be distributed as in the accompanying table,

Ingredient	Percentage	Pounds
A	10	500
B	20	1000
C	30	1500
D	30	1500
F	5	250
G	5	250
Totals	100	5000

where A might be aluminum, B might be borax, and C might be cryolite.

When these ingredients come to the mixing station, they are dumped into one of the several mixing machines. The mixing machines are similar to concrete mixers.

After the weight check discloses that the total of all ingredients is the proper quantity, a conveyor transports the mix to the designated smelter. There it will be loaded in from the top. Fusion takes place inside the smelter at temperatures varying from 2000°F to 2500°F. Continuous smelters are the tank type. Batches are fed continuously at one end and fluid glass is drained off at the opposite end. Batch-type smelters, which are more or less refractory tanks, have a spout on the bottom for draining. Batch production can also be carried out in a rotary smelter. The batch is either scooped into the smelter by manual handling or fed in by a mechanical feeder. The smelter is tilted to discharge the melted glass.

The cooling in the batch-type smelter takes place by the wet process. In this process a perforated basket is placed in the water tank located below the discharge spout of the smelter. The water solidifies the frit, and the basket screen retains the glassy particles. In continuous-type units, a conveyor carries the frit directly to the dryer. Quenching the glass by water-cooled rolls and cool air makes it an automatic drying process. The resultant enamel glass frit is called flake frit. When ground in a ball mill to the desired fineness, it is used in the previously described enameling process.

Connected with cooling are packaging and weighing of the finished product. Frit bags hold 100 pounds. They are either stored—if a stock item—or shipped to the customers in truck loads of 20,000 to 30,000 pounds or in carloads of from 40,000 to 80,000 pounds. Of course, smaller quantities are also shipped. One of the main factors in high production costs is the small-volume order.

Consumption depends largely on business conditions in the appliance industry. If appliance sales are down, orders are small. If that business picks up, customers tend to order larger quantities at more frequent intervals. A common characteristic of customers is that they call for batches. Because of competition, it is impossible to discourage small orders by charging higher prices for them. Therefore, the company is obliged to charge the same price per pound for stock items sold in 100-pound bags as for 10,000 to 30,000 pound loads or a larger quantity.

Questions. The student should know in advance that we are not dealing in this case with practices either wrong for or inadequate to profitable operations. Our task is to discover whether a cost reduction program can begin with improving production scheduling.

1. What factors indicate that some profits are not being realized because of the size of orders, production methods, and the rigidity of decisions related to production; that is, what symptoms indicate that the company could do better in the area of production cost—at least as far as the costs over which scheduling can exercise control are concerned?
2. List the obvious causes which force management to handle customer orders as they are currently handled.
3. Can management effect a reduction in production costs through other means than better production scheduling, for example, by price, delivery, and discount policies?
4. In analyzing the company's system of production, do you think that it is inadequate or improperly used to handle this kind of factory operation?
5. If you were in charge of production but particularly its scheduling, what if anything would you do differently and why?
6. Can you suggest something capable of facilitating the scheduling of production without affecting company policies relative to catering to the consumers' specifications?
7. What is your opinion about company inventory policy as it relates to production scheduling?

12-3. THE LINCOLN ELECTRIC COMPANY

A typical repetitive producer, Lincoln Electric Company, of Cleveland, Ohio, was founded in 1895 as a repair job shop for electric motors. Later it started to make its own brand of electric motors under the able leadership of John C. Lincoln. Presently, the company is the world's largest manufacturer of welding equipment.

The interest in arc welders began around 1912, when welding as a metal-joining process began to gain widespread acceptance. When the company started to concentrate its efforts on making welders, the motor production became only a sideline business. Yet making of motors was not abandoned. As a matter of fact, motor production gained further importance, because the welders the company manufactured used company-made motors. Thus, consumption of motors, both by outsiders and by the company's from its own inventory, was substantially boosted.

The company produces practically everything which goes into the welder: the motor, the parts which enter into the welder assembly, the electrodes, the housings, and the components of the motor itself (rotor, field and armature coils). The company makes a few selected models of arc welders, spot welders, and many other types of welding equipment having a total yearly dollar value exceeding 60 million.

The company's domestic plant is on a 30-acre stretch of land in Cleveland, Ohio. The construction and layout of the plant is such that it lends itself to repetitive production of certain standard and semistandard welding equipment. Basically, the Cleveland plant is divided into two manufacturing divisions, one for welding machines and the other for electrodes. This case is concerned mainly with the welding-machine end of the business.

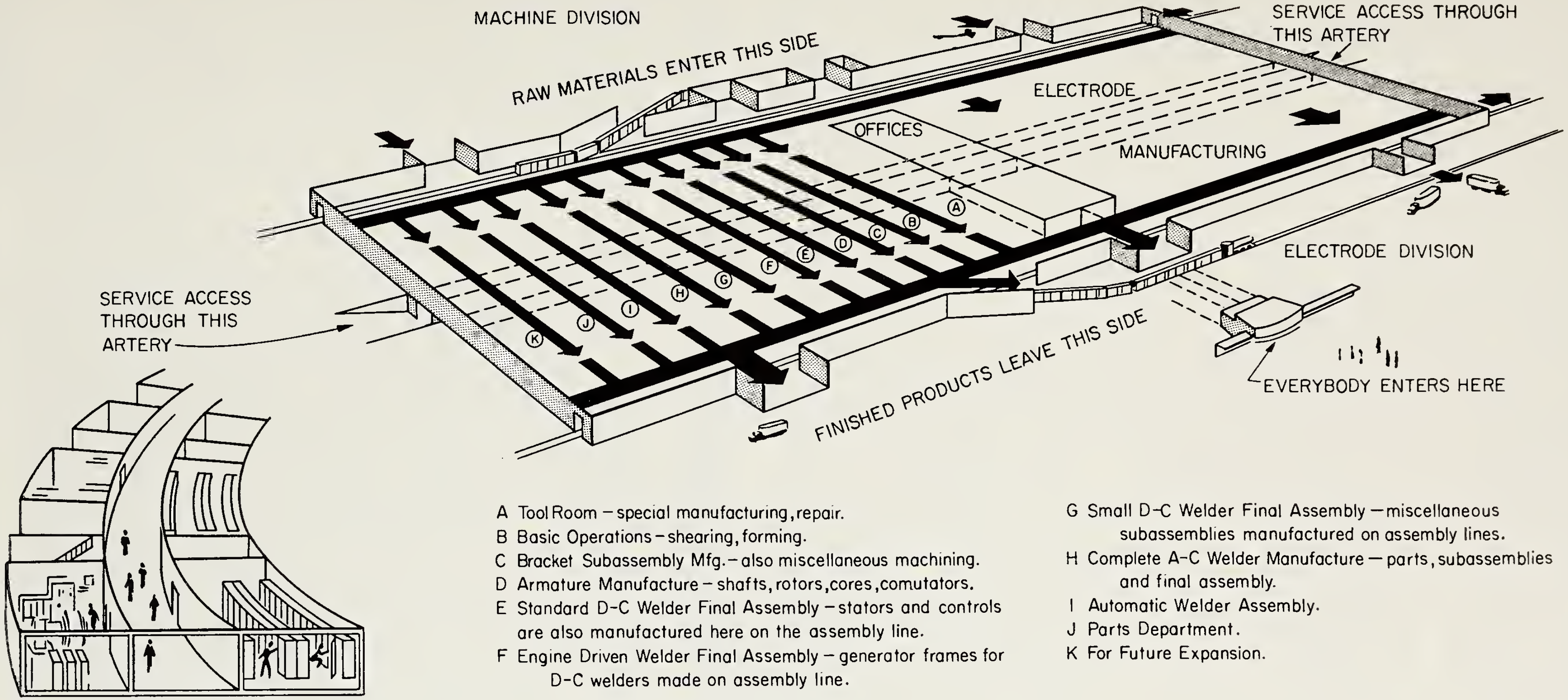
Since production capacity of the plant exceeds overall demand at any given time for any given welding machine model, the plant was cleverly constructed so that it is possible to manufacture several different welders on the same production line. Flexibility was possible because the production process of welders does not vary substantially with type. Although the shape and form of certain parts or even certain subassemblies differ, on the whole each welder contains parts which can be made in nearly the same amount of time. Thus in spite of apparent differences between the various welders turned out by the line, processing differences are confined to dimensions rather than function. For instance, while the number of turns in the winding of a given field coil or armature is bound to differ, the method of winding, the equipment which does the winding, and the winding skill which the machine operator must possess are the same. The punch press can make different parts in nearly the same amount of time and manner, provided that dies are changed between two different production runs. The assembly process also remains similar, if not fully identical. Of course, different shapes, sizes, frames and components go into each unit in the various welder classifications. Furthermore, each unit consists of electrical parts, such as shafts, rotors, cores, and commutators, and mechanical components which must be sheared, formed, welded, and machined prior to being assembled.

The motions and setups may differ, but the time requirements per welder tend to remain relatively constant from work station to work station. Thus, there is a definite balance between operations, both parts and component manufacturing as well as assembly work. This permits a relatively continuous flow of production regardless of which type of welder is being manufactured at any given time. Since, no matter how carefully it is designed, this kind of plant layout cannot be perfect in the sense that a production line of an assembly plant making one standard product can be, the company pays incentive rates to achieve a synchronization of operations along the production line. It should be noted that each work station (which is a small shop in itself) is able to turn out approximately the same amount of work as the next work station is able to absorb. Obviously, these problems were solved by the plant layout group at the time the plant was built.

Other problems related to the flow of production are solved by skillful production scheduling aided by the wage incentive (or bonus) system, which is a well-publicized and superbly operating system.

The plant layout was so designed that incoming materials and components are taken immediately to the machines or assembly areas where they are to be used. Thus, there is no requisitioning or waiting in line for supplies at stockrooms and storage areas; instead, employees see the materials and know when they reach a minimum level. The foreman also sees the materials because they are piled up around each work station. Accordingly, each work station has its own raw material storage and can use the materials as work requires. Raw materials are stored near the center aisles of the bays primarily to permit transfer of the parts (which have been made out of them) to the conveyors at the column line. This is significant, because from here the material moves to the next work station where the items turned out by the preceding work station are further processed or used in the assembly. In a sense, each work station makes its own parts and also performs the assembly of the parts which it makes as the product-in-process comes toward it from the preceding work station. It goes without saying that this method of handling stock permits visual control of inventory. Pilferage is no problem, since no one is interested in lugging home some heavy metal parts.

The assembly and subassembly areas are connected with a conveyor system. Since assembly times might conceivably differ depending on the welder which is being run, the conveyors extending along the column rows can be operated at speeds varying from 1 to 10 feet per minute. Ingenious switching and pickoff devices have also been designed to automatically remove certain subassemblies at points where they are to be used. The general nature of the plant layout is shown in the accompanying illustration. Generally speaking,


MACHINE DIVISION
RAW MATERIALS ENTER THIS SIDE
SERVICE ACCESS THROUGH THIS ARTERY
ELECTRODE
OFFICES
MANUFACTURING
ELECTRODE DIVISION
SERVICE ACCESS THROUGH THIS ARTERY
Ⓐ
Ⓑ
Ⓒ
Ⓓ
Ⓔ
Ⓕ
Ⓖ
Ⓗ
Ⓘ
Ⓙ
Ⓚ
FINISHED PRODUCTS LEAVE THIS SIDE
EVERYBODY ENTERS HERE

A Tool Room – special manufacturing, repair.
B Basic Operations – shearing, forming.
C Bracket Subassembly Mfg. – also miscellaneous machining.
D Armature Manufacture – shafts, rotors, cores, comutators.
E Standard D-C Welder Final Assembly – stators and controls are also manufactured here on the assembly line.
F Engine Driven Welder Final Assembly – generator frames for D-C welders made on assembly line.
G Small D-C Welder Final Assembly – miscellaneous subassemblies manufactured on assembly lines.
H Complete A-C Welder Manufacture – parts, subassemblies and final assembly.
I Automatic Welder Assembly.
J Parts Department.
K For Future Expansion.

General plant layout. (Courtesy of The Lincoln Electric Co.)

the output of each work station is in balance with the output of all other work stations. This permits a production-line type of operation, even though different products are being sent through the line periodically. However, one thing should be remembered, namely, that the products are made in periodic intervals. When demand for one type of welder is in a lull, the production of the welder which is in demand is scheduled. Since each departmental output capacity, regardless of the welder which is being run, is in balance, the progressive assembly operations can use conveyors conveniently. One should remember, however, that in order to attain a balance, all the items the line was to manufacture were carefully correlated with one another at the time the initial plant layout plans were formulated. Since each welder requires pretty much the same parts, except for differences in size or electrical characteristics, related operations are grouped into departments. Each department is a work station along the production line. The work station might consist of a crew or of one worker who runs all the machines in his department or work station. Since a great deal more than a few operation movements are involved, it is up to the men to coordinate their own efforts within each department (work station) and with the overall production requirements, both in the quantitative and qualitative sense. It must be obvious that such a coordination and cooperation would be impossible to attain unless the individual members of the production line received some sort of direct benefit from their work. Thus, the basis of the wage incentive system is production in accordance with production requirements.

Obviously, the production requirements are given to each work crew or department lodged along the production line by production scheduling through the production foremen. The crews must do their very best to attain the production requirements in order to keep the progressive assembly line moving. Unless each work station is making the necessary subassembly and the parts needed for it and adds it to the product moving by on the conveyor, the output of the plant as a whole is in jeopardy. Of course, some work stations are not necessarily engaged in the progressive assembly to make the final product, but are merely engaged in subassembly work. Nevertheless, output must always be adequate to furnish the assembly line with the required number of parts.

To illustrate how each work station operates, the gas tank station can be cited. Here different sizes of gas tank to suit the particular welders are made by the operator. He spot welds and then seam welds the several sections of the tank; tests the tank under air pressure; inserts the threaded bushings; thoroughly cleans the finished tank; and then stacks the tank for final assembly in a gasoline-powered welding machine. In many instances, the operator will also turn to the assembly line and weld or mount the subassembly which he made right into the workpiece coming to him on the conveyor.

While time study merely indicates the output, it is important to the functioning of this system that the employee strictly adheres to the output requirements. Without an incentive system, worker output would probably fluctuate to such an extent that the continuity of production flow could not be attained. Because management is willing to pay the workers in accordance with their contribution to company success, the rate of output per work station agrees well with the overall requirements.

When a sufficient number of sales orders for certain types of welders are accumulated to constitute an economical production run, the scheduling group decides on converting the "production line" to the production of the welder in demand. Assuming that the number of orders for a given welder is less than the economic lot quantity, the company makes a few extra pieces to round out the lot. In this way future orders can be shipped from inventory. When inventory is depleted and orders start accumulating for a given welder again, production is scheduled so that consumer "wanted dates" are met. It is a rather difficult task to accumulate orders and at the same time make sure that no customer has to wait too long for the execution of his order.

Dispatching is done on an informal basis, and when the schedule is decided upon, the foreman acting as dispatcher goes around the various work stations under his jurisdiction and checks on the availability of the raw materials. Since the material is visible and is stored adjacent to the point of use, it is nearly impossible that the work station would run out of required materials. Obviously, material storage is scattered in all parts of the welder-making area. The seemingly unsystematic piling of raw materials has a very definite purpose. It has reduced the necessity for an inventory control department and record keeping and placed the materials needed within arm's reach of the work station.

Because of the incentive pay, expediting is nonexistent in the Lincoln Electric Company. Since workers are familiar with all the welders which are recurrently manufactured, they merely want to know how many parts, subassemblies, or components must be completed by any given time. All employees will do their darndest to meet this need. In case of delay because of a machine breakdown, the maintenance department quickly removes the bottleneck and some help is given to the work station to catch up on the work so that the required output is attained. Otherwise, production would also be held up in other departments. Each department is an essential link of the chain and cannot lag behind without causing plantwide delays. To give men inducement to cooperate, the wage incentive system was designed. And it works. Employees, regardless of whether they are members of a work-station crew of several men or a one-man department, are forced to plan their work so that the required workpieces are made. While this means essentially job-shop type of work in each department, time would vary substantially if the worker had not planned his own moves with due regard of the overall output requirements of his work station.

Before every new run employees are told the kind of welder equipment and the volume which will be processed next. It is up to the employees as well as the foremen to check whether or not the material needed is available and adequate to carry out the "mission." Since each employee in a department acts much as the owner of a little corner grocery store does, he checks his inventory and plans his own work so that the work is accomplished. If a department would hold up production, it would be readily apparent. On the one hand, the particular work station would lose incentive earnings, and, on the other hand, the whole production line would lose money because of the bottleneck in question. Thus, there is a definite pressure on each department to adhere to the requirements. For this reason, expediting is seldom necessary. As it is, routing is not essential because the plant has been constructed with a natural built-in route. The processing instructions are almost unnecessary on repeat runs because employees "just know what they are supposed to do."

The production control work, aside from planning the production of the very first lot of a specific welder, consists only of scheduling. Since the employees know the various jobs which each of the welder models require of them, they consider the assignment as being dispatched when the schedule is submitted to them via their foremen. They know the parts which, for instance, must be blanked out of sheet metal, the number of armature coils which must be made to have enough for the motor which goes into the welder in question, etc. The employees will usually blank out or wind an economic lot quantity of each part or component. But this is rather a matter of course because the economic production lot of the welder model gives roughly the economic lot requirements as far as the components are concerned.

Supervision is relatively easy because workers do not "horse around" if they must finish something by a given time. Since smoking is not permitted on the premises, the workers do not even take time to smoke. There are, however, two 10-minute breaks per day.

It was stated earlier that, in case of a breakdown, the department might be given help in order to catch up on lost work. It is conceivable that one of the skilled maintenance men will be told to help out a department or a crew. Shifting of employees where they are needed is easy in this company because there is no labor union to object. All employees have an interest in the company's attaining its production goals because, around Christmas time, the bonuses are distributed and almost everybody receives a bonus check in four figures. The foremen therefore keep a close check on the employees, because cooperation and willingness to work as a team is one of the significant determinants of the size of the bonus an employee will receive. Of course, the output of each work station speaks for itself. The pieces turned out, so to speak, keep the score by which the performance of every work station is appraised. How much a person should produce is predetermined at Lincoln Electric through careful methods and time study, however. This has been then built into the plant layout. The task of the employee is to accomplish what must be done.

Questions. The Lincoln Electric Company case is an illustration rather than a case problem. It merely shows the relationship between plant layout, materials handling, and wage incentives as they make possible the repetitive production of several different models on the same production line. It is the task of the student to object to the company's system or to offer suggestions how the same results could be attained by different means than the company has actually selected. While no one knows whether the Lincoln Electric Company's system is the best, the company believes that it has solved the problem of multiple use of the same production facilities in the best way possible.

1. Do you see any symptoms which tend to indicate that the company's production control system violates the concepts of good production planning and control?
2. If any symptoms are found, determine their causes and suggest your own solutions to their elimination. You may contradict the solution which Lincoln Electric's engineers found. However, you must point out why you disagree with the method which Lincoln Electric applies.
3. What are those factors over which, in your estimation, a better control should be exercised and which, in turn, would permit a more orderly control of production and production efficiency?
4. Do you think that the inventory control system, relying largely on visual observation by employees and foremen, is adequate to attain the greatest possible efficiency? Give a detailed explanation of your answer.
5. Do you agree that the wage incentive system compensates for the "imperfect" balance between work stations when different welder models are being processed? Or do you think that more reliance should be placed on plant layout and industrial engineering in general?
6. Describe the type of production control system in force at Lincoln Electric.

chapter 13

Production Control in Continuous Production

CONTINUOUS PRODUCTION

That mass production can be divided into repetitive and continuous operations must be apparent from previous discussions. But where, precisely, repetitive production ends and continuous production begins is often an academic rather than practical question. When a plant operates on a continuous basis, the chances are that a single standard product is being manufactured and every product flows through the same production line as every other product flows through. Typical continuous production would be the meat packer's operation, where the live pigs enter the plant at one end and the meat products leave at the other. The plant is laid out in a certain way, and every animal goes through the same production process and ends up in some form of meat product.

Not only is the production process the same for every item which is being manufactured, but the rate of production is also the same. Usually the plant operates at a given rate per day, simply because the production line has been so designed that it has a fixed output capacity. Each work station has a certain amount of work which takes a predetermined amount of time, and employees do not have to be instructed at all, except at the time the production line is being run in (started up). Thereafter, employees just know what they are supposed to do without further instruction.

The fact that the plant is based on a production line does not necessarily preclude the production of minor variety. In a sense, the automobile assembly line is a continuously flowing operation, yet the line turns out cars which differ in minor details. The question whether these minor differences would classify the automobile assembly as repetitive rather than continuous production (because of not fulfilling the definition of one single standard product) is really an academic one. Essentially, the plant operates pretty much in the same fashion as if one single product were produced. We shall see later that only at the dispatching function and the inventory control function will there be some problems because of the differences.

The continuous producer does not wait for orders, but gages production to a sales forecast. Again reference should be made to the automobile plant, which, in addition, also tries to accommodate customer requirements. (Orders specifying those requirements are teletyped to the assembly plant.) Initially, however, the manufacturer decides on the type of product and produces at a rate which seems to fit forecast sales best. Since plant capacity is fixed, the chances are that demand in excess of the plant's output capacity is covered from stock. At the time of slack demand, the continuous producer does not necessarily stop, but continues operations and builds up inventory. In this way, surplus demand can usually be satisfied from accumulated inventories. If no inventory accumulation took place at an earlier time, the only way that heavy shipments could be made would be by overtime work or by adding a second or third shift. Of course, when all possible overtime is being worked and a third shift has been added, the plant cannot raise its output at all, but must refuse orders unless orders are backlogged. Ordinarily this would seldom happen, because the plant's capacity is usually gaged to long-run demand. Since sales are predictable through sales forecasting, the plant can usually prepare for seasonal peaks. The electricity-generating plant is a case in point. Regardless of how serious the demand, unless the generating capacity is available, the demand cannot be met. Generally speaking, however, a generating plant has excess capacity which is geared to peak demand. Barring special arrangements, electricity cannot very well be stored. This is different than a manufacturer who is able to produce ahead of time when capacity is available to prepare for peak demand. Of course, how far the manufacturer can go with inventory accumulation is another matter. It may often be cheaper to run a second shift when there is peak demand than to accumulate inventories over a longer stretch of time just to maintain an even rate of output. More will be said about this question a little later and in Chapter 15.

PLANNING FOR CONTINUOUS OPERATIONS

In this kind of large-scale production, the production control department sets the level at which the optimum and costwise best utilization of plant facilities can be realized. Operations are planned and controlled to meet demand, but without overtaxing the financial resources of the company. Unless earmarked for seasonal peaks, surplus inventory must be kept within bounds to prevent carrying charges from rising faster than the savings from continuous operations. Hence, the planner is mainly concerned with apportioning a fixed capacity in light of demand conditions whereby inventory levels will be in reasonable proportion to output rates. The ideal situation would be to operate without having any banks of materials as far as materials and in-process inventories are concerned on the one hand and finished inventories awaiting sales on the other hand.

Barring inferior quality, sales under competitive pricing depend largely on economic forces rather than on factors controllable by management. Thus, the continuous producer must be prepared to offer the product both at competitive prices and at the same rate that demand warrants. Profitability is then a matter of dovetailing production and consumption rates so well that the cost of production is kept at a minimum. This can be done, if we disregard the efficiency of the production line in the technical sense for a moment, through proper production scheduling. While the main concern is always the unit cost, other cost elements must occasionally be considered on their own merits.

The paramount importance of the sales forecast around which the whole production program revolves is apparent from Chapter 10. In face of fluctuating demand conditions, however, the development of a costwise favorable production program is not as easy as one would assume. While it is theoretically simple to start, stop, and restart operations, it is practically a rather difficult production problem. Thus, for instance, materials already on their way from vendor to plant or subcontractor to the assembly plant cannot be stopped; interrelated intraplant schedules cannot be suddenly disturbed; and layoffs cannot be announced in the Friday's pay envelope to be effective the next Monday. If the output rate must be increased, it is possible to do so only through overtime work, adding Saturday, Sunday, or second shift to the normal work week, which would, of necessity, involve rearrangement of employee work schedules and, consequently, prior notification. Raising raw material, semifinished work, or subassembly arrival rates to meet the main line's output rate depends on the ability of interrelated plants to comply with wanted dates at the ultimate user. The suppliers of parts, components, and raw materials cannot always react to sudden changes as fast as the central production control department desires. Thus, any decision, in view of the chain reaction it starts, must be made on a reciprocal basis.

But a desirable solution to the above problem will require more than changing the output rates. There is the urgent importance of keeping costs competitive, and this factor highlights the importance of costs under different output rates. Among other costs, inventory charges as well as fixed costs rise or fall and employment costs shift to higher or lower levels. The precise cost relationship can be seen in Chapter 15, Problem 3, page 716. Therefore, further elaboration at this point is not warranted. It is enough for the present purposes to make the generalization that by reducing the speed of the conveyor to 50% and letting one man take care of two operations, one effects a 50% cut not only in the output rate but also in total labor costs; excluding the indirect labor charges for materials handlers, maintenance men, etc. The indirect cost does not usually fall at the same rate as the direct labor costs. The overhead cost, however, will remain pretty much the same, since it is a fixed cost having little to do with the output rate.

Whatever buildup in inventories is planned has further connotation in output rates, operating costs, and carrying charges. Hence, the decision as to when to change to which rate of output is a complicated one based not on convenience but on monetary considerations. Although the scheduling procedure does not deal explicitly with costs per se, in the final analysis the costs are the determining factors underlying most production decisions in continuous operations. Truly enough, the production control group looks at the allocation of capacity so as to meet consumer demand in the most advantageous fashion, but that cost factors are involved is borne out by the breakeven chart shown in Fig. 13-1. The cost, profit, and revenue relationship is depicted by the horizontal and vertical axes. The horizontal axis represents output, the vertical axis, total cost; the slanted line, variable cost; and the diagonal line, revenue. The dashed vertical lines represent 1) minimum output at which neither loss nor profit is made and 2) maximum output and maximum sales (the ideal situation). In the latter case, the difference between the cost and the revenue lines indicates the potential profit if the quantity produced can be sold at the same rate as production turns it out.

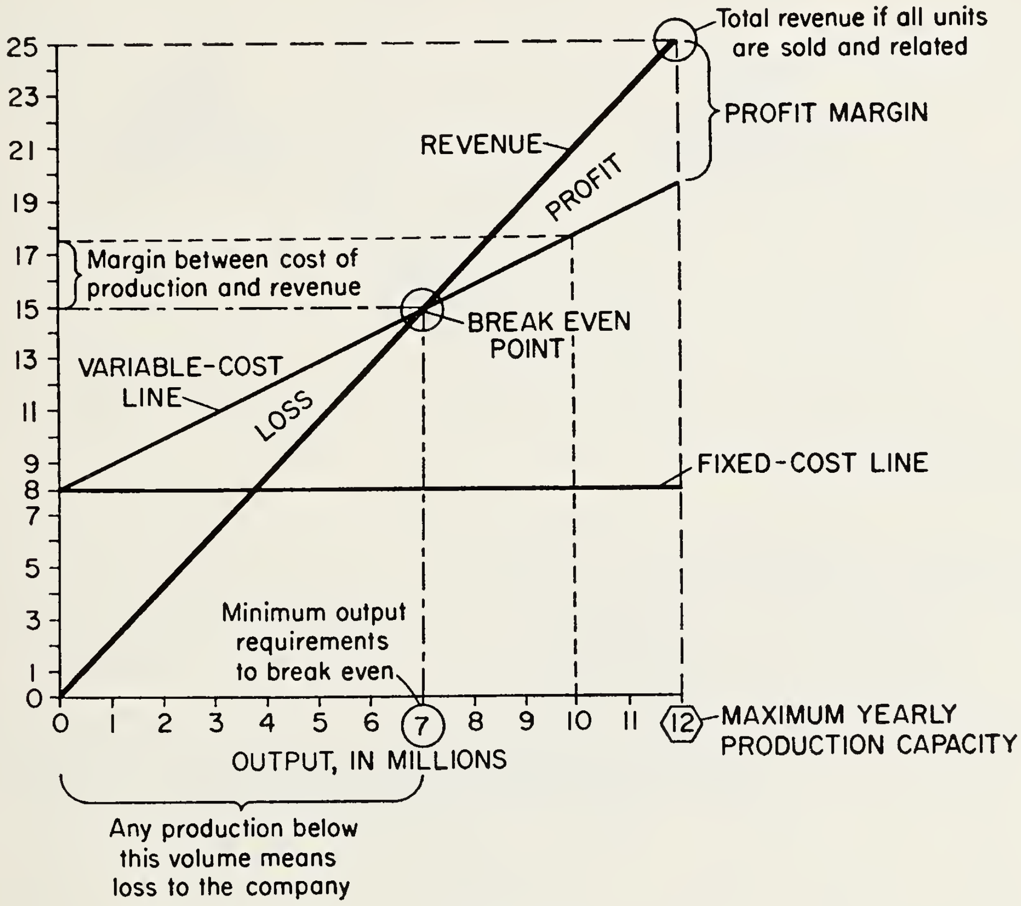


FIG. 13-1

Output at the 7-million level would merely recover costs; below that the company would incur a loss as indicated by the diagram. When there is 10 months production equal to 10-million units, profit would be the difference between \$15 and \$17½. Other costs, however, including costs of storage, inventory carrying charges, and distribution costs, must come out of this amount.

While Fig. 13-1 might exaggerate the magnitude of profit based on given sales volumes as well as accompanying costs, it indicates the intimate relationship of these three factors when one formulates plans for operations not only at the final assembly stage but also at the subordinate manufacturing, subassembly, or preparatory stages. The diagram does not tell the whole story; for it disregards seasonal or cyclical fluctuations in demand. If total yearly production capacity is 12 million but demand fluctuates from month to month, the question that arises is how the sales volume can be met from the fixed production capacity. If demand for the company's product were uniformly divided throughout the year, no planning problem would arise. But the fact is that demand tends to fluctuate both cyclically and seasonally.

The diagram, moreover, indicates a seemingly high margin of profit at the twelfth month at maximum capacity utilization. In reality, however, operating profits would be automatically halved as a result of other costs which tend to arise (distribution expenses, storage costs, etc.) and must be taken out of the sum which remained after the costs of production were taken care of. If the normal distribution costs are 50% of the margin of "profit" indicated on the chart, one can see that the diagram is not at all out of line.

If monthly capacity is 1 million and the yearly capacity is 12 million but in some months demand falls way below the 1 million limit and in some other months it surpasses 2 or 2½ million, it is essential to make provisions to apportion available plant capacity over the year so that production for stock takes place when sales are below the capacity of the plant. Excess capacity can be advantageously utilized by building up inventories to cover surplus needs during seasonal or cyclical peaks. The sales forecast, the already described tool capable of predicting demand conditions, is then the basis of the scheduling procedure, which has the purpose in continuous production of serving as the indicator of demand conditions and capacity allocation in light of cost, technical capabilities, and other controllable elements. At any rate, the goods must be available at the time consumers call for them in the market place.

The capacity of a plant is comparable to that of a jug. No container can hold more water than its capacity. Yet because sales might at times exceed capacity, the plant must produce ahead of demand and store the surplus if it wants to be prepared for a seasonal or cyclical peak demand. In this sense, production for stock is a necessity. The only question is how much can be stored at a rate commensurate with the company's financial interest. That the goods must be available when the consumer wants to pick them off the shelf goes without saying; otherwise, the sale is lost and prospective customers are turned to a competitor's product. Barring a monopolistic situation, a sale is generally lost if the consumer cannot be served as he wants to be served. Just place yourself in the position of the electricity consumer. If the electricity would not be available when the switch was turned on, consumers would turn to alternative power or electricity supply. Not only would profits be lost, but the costs would also undergo changes, because with lower sales figures the overhead charges per unit of output would rise.

If the sales conditions versus forecast sales are assumed and related to plant capacity as shown in Fig. 13-2, it becomes apparent that evening out production capacity with demand conditions is physically possible; this does not, however, imply that it is financially desirable. It might be more advantageous to either shut down or work overtime as demand conditions warrant than to provide continuous work for the employees and keep the plant uniformly busy.

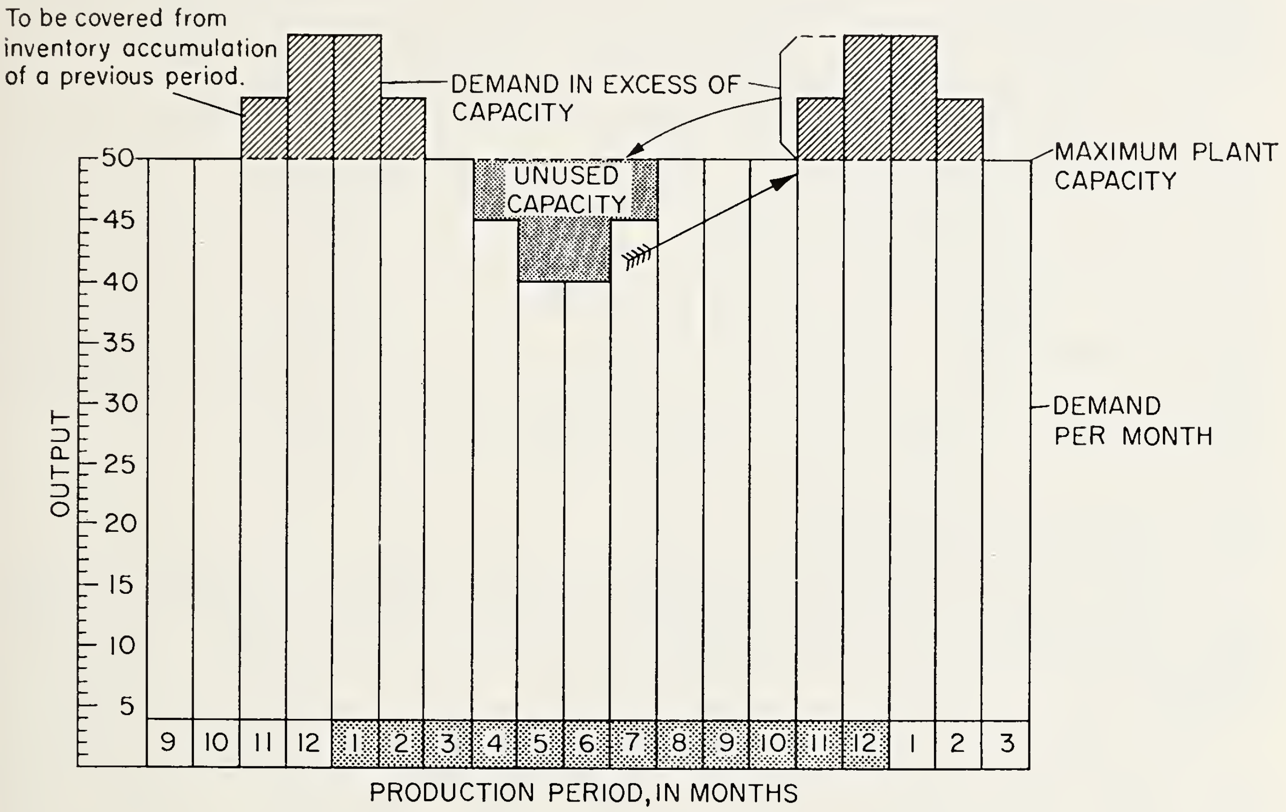


FIG. 13-2

Figure 13-2 shows that the unused capacity in April, May, June, and July is adequate to compensate for excess demand in November, December, January, and February. Hence, it becomes the production planning department's problem to distribute production capacity and decide on inventory accumulation so that, in spite of the obvious handicap, low costs of production are incurred without paying unduly large inventory carrying charges. It is evidently desirable to operate on an even keel, but only if this does not impose prohibitively high financial burdens in the inventory sector. Accordingly, it might at times be more advisable to produce in accordance to demand and work overtime, second, or third shifts rather than to build up inventories over a long stretch of time which would precipitate costs of storage far in excess of the savings attained from continuous operations. Of course, if the plant capacity refers to a 24-hour day, the choice is reduced to refusal of orders or to operation at maximum plant capacity during lull season in anticipation of later heavy demand.

This brief description of the overall planning problem indicates that mere accomplishment of production objectives is not the underlying goal of production planning and control. Its main purpose is to do so with the least cost per unit of output, including storage and distribution costs. Therefore, the implementation of production plans in terms of routing, scheduling, dispatching, and expediting is subordinated to the overall cost consideration on the one hand and to inventory, budgetary, and sales policies on the other.

The scheduling problem itself brings even more factors into play. Overall capacity of the central unit—for example, the assembly plant—is the controlling factor. Everything must be gaged to final assembly. But the subassemblies, feeder assemblies, and parts manufacturing are bound to enter the picture and will impose limitations on the planning of flow at the central unit. It must be apparent that in order to keep the flow of production in continuous stream, the output capacities of all subservient producing units must be duly taken into consideration at the time the production program is worked out.

THE MASTER SCHEDULE

It would be inadequate to discuss only the master schedule here. Therefore, everything which master scheduling involves will be grouped under this section.

The basis of the master schedule is the already described sales forecast. As was pointed out in Chapter 10, the sales forecast is a prediction of how many units the company expects to sell under prevailing economic and competitive conditions. However, before the sales forecast becomes a manufacturing forecast, top management of the company will pass judgment on the forecast. Pending advertising and sales promotion plans would naturally influence this judgment. Accordingly, venturous management might raise production goals above the forecast sales in the hope that, through vigorous sales effort and good price policy, sales will rise. In turn, a conservative management might do the reverse and decide to produce less than the forecast sales. Evidently, all these decisions are based on intimate knowledge of cost factors related to any one of the chosen courses of action. The inventory carrying charges are usually compared with possible savings resulting from greater production volumes. The elasticity of demand and price policies must be carefully analyzed to see what the unit cost would be with different sales or production volumes. Although these men are making a judgment, it is based not on guesses but on empirical data. After the desirable output quantity is decided upon, a master schedule will be made, and subsequently it will be translated into manufacturing schedules.

The master schedule can take a tabular or a chart form (see Fig. 13-2). This author prefers everything in chart form because charts are clear, concise, and easily understood. For planning purposes, nothing can be much better than a chart. In the shop, however, people prefer to see things in tabular form. Obviously, the planners like to look at the overall demand as it is divided into monthly and quarterly production requirements; production men down in the shop, however, want to see things in figures. The latter are interested not so much in the overall picture as in the specific section of the total production volume that concerns them.

It follows from the preceding discussion that the scheduling procedure only starts with the master schedule. Subsequently, the master schedule must be translated into shop production orders and requirements. In practice, the shop production orders are probably more important than the master schedule. A perfect master schedule is of little value to the operating units unless it has been properly developed into detailed schedules. Furthermore, before the year is over, the chances are that the master schedule, including all detailed manufacturing schedules, will undergo substantial revisions. Obviously, monthly production rates at the early part of the master scheduled period are more likely to be accurate than toward the tail end of the master plan. Evidently, the immediate future can always be better foreseen than the distant one. For this reason, adjustments are usually made after the conclusion of each quarter year. As a matter of fact, adjustment might be made month after month, in which case we speak of a rolling schedule. The next month's output is adjusted in light of current inventory position and economic developments.

TABLE 13-1

Month	*Units, in millions*
January	30*
February	31†
March	32
April	30
May	28
June	26
July	24

* Includes 2 million inventory carry-over.
† Includes 2 + 1 = 3 million inventory carry-over.

A typical master schedule is reproduced in Table 13-1. Although January is the starting point, that does not necessarily imply that the forecast must start with a calendar year. The company can operate on a fiscal year or on any other basis. In some plants, the master schedule represents output requirements over a half year or even shorter period. In some other companies, the master schedule might refer to 24 months production in view of the necessity to include a large enough time span to alleviate the disturbing cyclical and seasonal fluctuations in demand. Thus, almost two years is necessary to get prepared for excessive demand conditions. Because of the expensive nature of stockpiling, this situation is applicable only to unique production situations. Basically, the company's individual situation will determine the method and the steps which the master scheduling procedure will take.

It should be noted that when the sales forecast wanted date is January, the master schedule will probably call for a different wanted date. Depending on lead times in the various stages of production, the master schedule wanted date could be a much earlier month than January. If the above-mentioned time lag is disregarded for a moment and we assume that the sales estimates call for 28, 30, 35, 30, 28, 26, 24 million units from January until July, respectively, the question that arises is when the output that exceeds the plant's monthly capacity of 28 million units will be produced. Since the breakeven quantity is 22 million units, the sales forecast does not precipitate special considerations on the minimum side, but it must still be decided how the overtime work will be handled. The requirements indicate that in February, March, and April more is needed than the plant's maximum output capacity. Total requirements over the seven months period call for 201 million units, while the normal one-shift output is 196 million units. But the 12 million units above and beyond the plant's 28 million units per month capacity must be turned out within 4 months. When the overtime work will be done depends largely on cost considerations, particularly storage costs. Thus, the master schedule might call for the amounts, in addition to the 28 million normal one-shift capacity, listed in Table 13-1. The master schedule is evidently nothing else than a mimeographed sheet on which the total quantity of an item, broken down into monthly requirements, is listed. When one should produce ahead depends mainly on the costs involved in inventory charges, overtime differential, and Saturday and Sunday work differential versus inventory carrying charges and many other cost considerations.

If the above requirements and the capacity limitation refers to a three-shift operation, it is apparent that the planning for the January to July period must start far enough in advance of January to build up inventories so the goods will be ready when needed. Furthermore, it should be emphasized again that January production possibly refers to March or April sales. In other words, when the sales forecast says March or April, the master schedule refers to the preceding December or January. The master schedule of an automobile assembly plant might look like Table 13-2. Different major components have different rows. The first row might refer to the major assembly and the following rows to the various feeder assemblies. We speak here about assembly primarily because only the assembly end of manufacturing is usually a continuous process, while the manufacturing of parts is usually repetitive.

In other types of continuous production in which the components are transformed into finished products, the master schedule consists mainly of monthly output requirements over a predetermined period for which the master plan was prepared, as shown in Table 13-1.

Chemical, cement, refractory-product, and meat companies would schedule only one item per month. This is done as if the plant were nothing but a huge machine.

TABLE 13-2

TRANSMISSION	HUBCAPS	WIPERS	ENGINE	WHEELS, 5 PER CAR	CARS			
360	1800	720	360	1800	360	1	JANUARY	MASTER SCHEDULE
360	1800	720	360	1800	360	2		
360	1800	720	360	1800	360	3		
360	1800	720	360	1800	360	4		
350	1750	700	350	1750	350	1	FEBRUARY	
350	1750	700	350	1750	350	2		
320	1600	640	320	1600	320	3		
320	1600	640	320	1600	320	4		
300	1500	600	300	1500	300	1	MARCH	
300	1500	600	300	1500	300	2		
300	1500	600	300	1500	300	3		
300	1500	600	300	1500	300	4		
350	1750	700	350	1750	350	1	APRIL	
350	1750	700	350	1750	350	2		
360	1800	720	360	1800	360	3		
360	1800	720	360	1800	360	4		
360	1800	720	360	1800	360	1	MAY	
360	1800	720	360	1800	360	2		
360	1800	720	360	1800	360	3		
360	1800	720	360	1800	360	4		
360	1800	720	360	1800	360	1	JUNE	
360	1800	720	360	1800	360	2		
360	1800	720	360	1800	360	3		
360	1800	720	360	1800	360	4		
350	1750	700	350	1750	350	1	JULY	
350	1750	700	350	1750	350	2		
350	1750	700	350	1750	350	3		
350	1750	700	350	1750	350	4		
340	1700	680	340	1700	340	1	AUGUST	
340	1700	680	340	1700	340	2		
340	1700	680	340	1700	340	3		
340	1700	680	340	1700	340	4		

The master schedule of automobiles, Table 13-2, is, of course, oversimplified. In reality, the various body styles would require the assembly of different components, not to speak of special customer requirements such as standard or hydraulic shift, heater or no heater, or special glass or windshield. For the sake of simplicity, the example assumes uniform transmissions, wheels, engines, etc. To take care of these differences, the master schedule must be refined and turned into detailed *manufacturing schedules.* The latter not only provide a detailed breakdown of the components which make up a car but also serve as an authorization to the various departments to make a given quantity of the items with which they are concerned. As far as the production control department is concerned, the approval of the master schedule is the authorization. Anything which is necessary to attain that master schedule goes with that authorization. Thus, production control will instruct the departments in their specific part in the production program. Nothing may be done in a department without authorization, and as soon as the departments receive their schedules, supervisory personnel will know how many shifts and how much overtime work are involved and can inform assembly workers sufficiently ahead of time. The consequences of failing to do so would go beyond the scope of this discussion.

PRODUCTION LINE PROGRAMMING

The capacity of the final assembly (and associated subassemblies and feeder assemblies) is known in advance. Although the line can be operated at reduced rate, the fact is that it was built with a given output rate in mind, as explained in Chapter 8. Generally speaking, it is in the interests of management to run the plant at normal rates, usually the one-shift capacity, as long as inventory accumulation is not excessive in the financial sense. If the line is synchronized at 1-minute work cycle, the very maximum the plant can turn out in one shift is 480 units; in two shifts, 960 units; and in three shifts, 1440 units. Thus, the very maximum the plant can turn out per day is 1440 units. Apparently, then, the length of time required by the production cycle of a serialized production line determines the capacity of the line. Delays can hardly occur, because conveyors tend to keep production moving at a regular pace—barring mechanical failures or delayed arrival of materials at any given work station. Therefore, once material has entered the line, it will usually finish the production cycle without change of sequence and without any disturbance.

Once the material starts its journey down the line, it can be calculated with mathematical precision when it will reach the terminal work station and the shipping or stockroom. Some plants are capable of putting out one vacuum cleaner or TV set every minute or one automobile every 3 minutes. Of course, one should not jump to the conclusion that it takes only a minute to produce a TV set or 3 minutes to produce an automobile. The production cycle from start to finish might take several hours. But once the various work stations along the production line are supplied with the appropriate in-process material, one unit of the product comes off at the end of the line in regular intervals. Just as in baseball a team can expect four runs when a home run is hit only if the bases are loaded, so in industry the work stations must be loaded before a TV set or vacuum sweeper can come off the production line every minute. In other words, work in process must permeate throughout the production line before the company can count on a given number of workpieces. Once the pipeline is filled, the planner can work with a fixed plant capacity.

Thus, if production capacity is 480 units per shift, the planner knows that at the end of each shift he can count on the availability of 480 units without any intermediate scheduling of operations along the production line. Although the production line might consist of 1000 different work stations, scheduling is done as if the line were nothing but one single big machine.

The reader should imagine the moment when the whistle blows and the conveyor stops. At this moment everybody leaves his work station. The workpieces are left on the bench or conveyor belt in the same shape and form they were in at the very moment the whistle blew. A motion picture stops when a fuse blows, and when the fuse is replaced, the film picks up at exactly the same spot where it left off. The production line works in a similar manner.

Even though the rate of production flow is continuously controlled by the speed of the conveyor, a normal fallout rate might reduce the theoretical maximum output by a predictable reject rate. Assuming a 1% reject factor, the output capacity of the line is not 480 but 475 per shift (480 − 5 = 475).

In other companies the reject rate has little to do with the output rate because, as inspection stations scattered at strategic points throughout the production line find a faulty product, the imperfect unit is taken out of the stream of production and replaced with a good piece (possibly a repaired one). As TV sets, for example, move down the assembly line, the chances are the movement will not be interrupted at all and the same product will come off at the end of the line, unless it had been substituted. Employees in such continuous production line situations do not leave their work stations; or if they do, they request replacements. When a worker switches on a light, a replacement comes and takes over until the operator returns. The problem is different when there is no conveyor system. Although such a regulation would be equally advisable, the production line is not quite as perfectly synchronized. Employees may leave occasionally, and in those plants output rate might, of course, fluctuate within limits. A little delay in one work station may cause several additional delays elsewhere, and the fact of the matter is that the output rate is not as fixed as has been indicated. If reduced output is required, some employees may operate two work stations and the plant will then operate at half the normal output rate.

In most production lines, however, the problem is not so much that of work station and employee efficiency as it is of lack of availability of materials. Therefore, inventory control plays an important role in certain types of mass production.

SUBSTATION AND FEEDER-LINE PROGRAMMING

A production line resembles a network of railroad tracks leading into a big city's railroad terminal. The main production line is supplied with parts and components by the various subassembly and feeder assembly lines. The movement of the main assembly (final assembly) evidently depends on that of the subassemblies; the latter in turn depend on the movement of the feeder assembly lines. It is therefore of considerable importance to synchronize all the related assembly sections. This process of synchronization is based on careful time studies whereby the subassembly station and the feeder assembly station must supply work at the same or at a higher rate of speed than the movement of the final assembly.

If the final assembly takes a minute at each work station, it is evident that plant layout and time study engineers must develop a subassembly line which can feed the main assembly at a 1-minute rate. The same thing is true as far as the feeder line is concerned. Since this is basically a plant layout problem at this point, no further explanation appears to be necessary. It is important, however, to remember that prior to the start of the operations, considerable thought is given to the problem of creating a smoothly flowing production line. Here the subassembly line is considered as if it were a single work station. The same thing is true as far as the various feeder lines are concerned.

Suppliers' Scheduling

The limited number of subassemblies and feeder assemblies makes it relatively easy to create an uninterrupted flow. Considerably more complicated, however, is the synchronization of suppliers' activities with the production line—primarily because the supplier's location is usually different from that of the prime producer. Unless the supplier is located nearby, it is difficult to assure that the part or component which the supplier or subcontractor furnishes will always arrive in the plant at the appropriate time with reference to the affected work station in the assembly. Unless the various interdependent work stations can be synchronized in the time sense and production can move properly, in-bank or temporary storage areas must be built into the production line. Here materials must be produced through overtime work or through different work schedules (more working hours than the rest of the line spends on the premises) to make up the difference needed to keep the line moving. This means basically two things: 1) determination of the in-bank time and 2) determination of the quantity which must arrive at the assembly point of use at regular intervals. Obviously, both the in-bank time and the quantity will vary with the nature of imbalance. If the item is subcontract work, the in-bank time may depend on the probability of delay between two shipments. This will also determine the safety quantity which the plant must keep to make sure that the line never runs out of materials which could hold up the movement of the production line as a whole.

If a subcontractor supplies the material, it is important to let him always know what is needed by the line and in what approximate intervals. Usually the order is given in open-end contracts, and if there is an increase in the quantity needed, the contractor will have to furnish the line with the needed materials. The assembly plant will gage its production releases to the movement of the line, which will usually contain a certain safety quantity.

This problem is analogous to one which the railroad solves through scheduling. The mainliners move through different cities and reach given junction points. For commuters to get on the mainliner, it is essential that the commuter train be scheduled to arrive at the junction point sufficiently ahead of the scheduled arrival time of the mainliner so that even if the commuter train is a bit late, there is still ample time for its passengers to catch the mainliner. In the same way schedule of arrivals at a plant must contain some extra time. Here we are dealing mainly with quantities of materials per time unit. How much ahead of time of need (and in what quantity) any given item should arrive will have to be determined through careful calculations of costs of storing and capital expenditure, in addition to probability factors based on delays. When strikes may be expected in a supplier's plant, this may also influence the in-bank time.

Lead Times and Float Times. To be sure that materials, parts, components, and subassemblies arrive in the plant at the proper time, the production control department must gather information about the supplier's lead time. Lead time simply means the time it takes a subcontractor to deliver the material after an order is given him. Obviously, lead times vary with business conditions, and it is essential to revise them periodically. The lead time might be 3 weeks if 500 units are ordered, but not necessarily 6 weeks if 1000 units are ordered. Thus, lead times may vary even with the size of the order quantity. The lead time will be an important element in the determination of order quantities on the one hand and of date of releases on the other.

Lead time depends to a large extent on whether the plant keeps materials in stock or whether the materials arrive directly at the assembly stations. In the former case, the lead time assumes a different importance than when the material is heavy, bulky, and expensive. If the latter is true, the scheduler must make sure that the supplier's shipments arrive at just about the time that the assembly station needs it, give or take a few extra hours. The in-bank time in that case will probably be passed in a railroad car rather than on plant premises. Unloading will begin at just about the time the material must be moved to the assembly floor. It may be cheaper for a company to pay the demurrage charges for the railroad car than to unload the material several times and in several places.

In the latter case the float time may be important because it may be important to know how long it takes the product to permeate through the assembly line. The float time refers to the amount of time needed to fill every work station with in-process goods. If the line is synchronized at a 1-minute cycle, then 1 minute after the float time a unit of output will come off at the end of the line. Float time may help to perfectly synchronize the arrival of parts at the various stations precisely at the time they are needed. Dispatching may be concerned with this in such places as automobile assembly plants, where a wheel of given color and size must meet with a specific car at a precise time at the appropriate assembly station.

The importance of lead time also depends on the specific quantity which the company orders or schedules to come at a given arrival rate. If the volume is large, at least large enough to last a few days, the lead time will determine when the next batch should arrive. The float and the capacity of the plant, including the rate of movement of the assembly line, will automatically tell when the bank of materials is depleted. This is the time when the new shipment must arrive, that is, just about the time when the last piece of the in-bank material is being used up. Theoretically, as the last unit is used up, the new batch should arrive and enter the production line. Apparently, then, raw materials, parts, and subassembly or subcontract work are made in batches, economic lots, bundles, etc., and only the production line, or the subassembly and feeder assembly lines associated with it, are continuous-production lines. In such instances it is of considerable importance to work with accurate and reliable lead times. The production of parts and components in economic lots might or might not be associated with continuous production.

Shipment Releases. When the company's assembly plant operates continuously, but the sister plants or subcontractors operate repetitively, the lead times can also serve in the determination of shipment releases. Since the bulky nature of raw materials would create a tremendous storage problem and costly handling and rehandling of materials, the continuous producer does not want to have any excess amount of material lying about the shop or blocking passages along the assembly line. There is a normal bank of materials which must be refilled as the line uses them up. Shipment releases are given to the suppliers so that the materials are replenished continuously. When the sales forecast governs the rate of production, the shipment releases must, of necessity, be tied up with scheduling, and to give proper shipment releases, the lead time is of great importance.

SUBSIDIARY PLANTS' SCHEDULING

The central production control department is located in that particular plant of a company which turns out the finished product. In the automobile industry this would be the assembly plant. The motor, the transmission, the battery, and many other parts of an automobile are often made by sister plants. These subsidiary plants must, of necessity, be subordinated to the commands of the production control department of the final assembly. The movement of materials between interrelated divisions is accordingly directed by the central production control department, which makes all schedules and gives releases, shop orders, and other production information to the local production control departments of the subsidiary plants.

The central production control office does not direct the internal affairs of any subsidiary plant; it merely gives the quantities needed at given dates, while allowing for the lead time required by each division. The subsidiary plant's production control department must subsequently arrange its own schedules in such a manner that the required quantities are completed in accordance with output schedules—the master schedule—of the central production control department. The various parts and outside supplies that the subsidiary plant needs are evidently not the responsibility of central production control. The production control department of the subsidiary plant must worry about that. Nevertheless, since the lead time of the subsidiary plant depends on the lead time of many other interrelated plants upon which the subsidiary operations depend, it is important to know some of the major problems the other fellow might experience if we were to, say, double the shipment requirement. While the subsidiary plant's capacity might be adequate to deliver double production, the plant might be handicapped by its inability to receive materials from its own suppliers. For this reason, the lead time will not be something very rigid, but will depend largely on the size of the order or release schedule. If volumes are larger, the lead time might be considerably greater, since a whole series of interacting lead times must be taken into consideration.

OVERSTOCKING AND INVENTORY MANAGEMENT

Since continuous production is based on a sales prediction, the chances for overproduction and overstocking are present no matter how scientifically the sales forecast has been developed. Evidently, then, it is one of the subfunctions of the production planning and control group to keep finished inventory costs at a minimum. The out-of-pocket costs must be particularly avoided, since the normal handling and storage costs such as rent, heat, and light are usually fixed. If, however, warehouse space must specifically be rented to house the surplus production, this cost becomes an additional one above and beyond the normal fixed charges. This is what must be prevented.

Furthermore, there is often an obsolescence factor in surpluses, particularly if the overproduction falls at the tail end of a model or style year. After the new model is introduced, the old model tends to lose a considerable amount of its original market value. Thus, the revenue line and the production quantity versus production cost lines in Fig. 13-1 can easily lose their original validity. In some style goods, the surplus product might be fully useless and the producer might be forced to give away the surplus product rather than sell it at a reduced price. (If a producer were to lower the price on the dealer's surplus inventories, many prospective customers would wait until the end of the season to take advantage of the lower sale price, with ruinous affect on future sales on the one hand and public relations on the other.) This might equally be true of military products, where parts and components change quite frequently because of a rapid technological obsolescence. The same thing is true in many other industries which are subject to violent technological changes.

Some undesirable out-of-pocket-expenses might be involved in storage. If, for example, automobiles must be stored longer than the anticipated time, they must be kept clean and batteries must be recharged. These are not the ordinary storage costs, and they would add only to the cost and not to the value of the product.

The interest charge on capital tied up in idle inventory is a cost of considerable magnitude. Raw materials and vendor items are acquired in accordance with production schedules. Hence, if the error in sales forecast becomes apparent sufficiently ahead of time, the issuance of releases can be stopped or postponed. Thus the interest on capital can be avoided, as can bank interest paid on inventory in dealers' hands. (The latter includes the variable material and labor costs.)

Inasmuch as it is in the power of the production control group to keep down inventory costs (on finished inventories, anyway) including capital cost, the aim should be to avoid scheduling production for which no demand exists. It is poor business, of course, to produce for stock even if both storage space and money needed to finance operations are available. This is so because alternative investment opportunities for the money must always be considered. Idle capital is usually not an unproductive fund but is instead money which is employed in some income-producing manner. In other words, if the use of money in alternative investments would have brought in some income rather than being idle production for stock, the latter would represent nearly the same thing as an out-of-pocket cost even though there was no loss in fact.

PRODUCTION SHUTDOWN TO LIQUIDATE INVENTORIES

Seasonal inventory accumulation in anticipation of high sales once or several times during the year will have its natural liquidation period. Hence, this is no specific concern to the firm. The involuntary accumulation of inventory is the problem! For this reason, it is essential that production control keep a close tab on sales and immediately adjust output volume in accordance with actual development of markets. If for some reason or other sales did not follow the initial prediction, timely action might still remedy the situation. Economic conditions change, despite constant adjustment of output rates by the production control department. Hence, overproduction is always a possibility. It would not make much sense to stockpile when all economic indicators point toward a declining rather than an improving business outlook. In light of the economic conditions the production control group might recommend a cutback in production to reduce inventories in the hands of dealers and distributors. To do so, either a complete shutdown or a partial cutback might be considered.

Occasionally it is more advisable to accomplish the liquidation of inventories through a gradual cutback of production than through a complete shutdown. If done through this method, the main requirement is to produce smaller quantities than sales would warrant, until the inventory surpluses were reduced to a manageable level. Although by this method plant facilities are only partially, and probably inefficiently utilized, the fact that they still operate might mean savings in comparison to a complete shutdown. In the steel industry, for instance, a complete shutdown would cause actual damage to equipment, as well as substantial fuel losses. Imagine that furnaces were completely cooled off and had to be reheated when production was to start again. The loss in fuel would be tremendous. Also, the furnaces must be cooled off quite gradually to prevent them from cracking. In other words, in steel and in some other selected industries, it might costwise be better to operate even if at a reduced rate than to shut down. The savings in fuel, repair, and layoff costs might more than compensate for the greater cost of carrying on additional amount of inventory. However, the rate of output must always be so determined that the rate of sales will always exceed current production volume.

Other considerations might also enter into the managerial decision. Equipment in use does not decay as fast as equipment which stands idle; the premium paid on unemployment compensation insurance varies proportionately with the degree of employment stability; unemployment funds are not depleted if employees are given a chance to work at least 3 or 4 days out of every week. Hence, there are some important arguments for continued but somewhat inefficient operations.

Inventory depletion periods, however, do not have to be complete wastes in employee time and employment stability. The vacation schedule might be so arranged that vacations will coincide with inventory liquidation. Because layoffs and shutdowns cause all sorts of record changes, such as cutting employees off the payroll and reregistering them when they are recalled and getting production started from scratch, production management tends to think twice before deciding on full-scale layoffs.

ROUTING FUNCTION

In the job shop, each order is quite unique and must be routed through the plant individually; in the repetitive type of production, processes are quite similar although major variations requiring special care on the part of production control might still occur; but in continuous production, the whole planning function, of which routing is a part, is performed at the time the plant is laid out. Hence, the mode of processing is determined *prior* to laying out and tooling up the plant. After the pilot run is completed and operations can be considered perfect in that most of the bugs are taken out of the production line, operations should move smoothly through the line. Therefore, after the initial difficulties are overcome, there is no need for specific production instructions.

Despite such perfection in production-line arrangements, some snags in production are not unusual. The arrival of a part which enters the product at a given work station might be delayed by a snow storm, or a machine breakdown in one of the subassembly operations might create a bottleneck. In such instances a rerouting of operations to bypass the trouble spot becomes the function of production control. Alternate routes must evidently be established when nonstop operations are important.

In view of the limited need for routing work in continuous operations, the routing function is done on only a part-time basis by some member of the production control department. It amounts to hardly more than routine duties which occasionally must be performed. These might be concerned with reroutings, as mentioned above, but they are more likely concerned with changes in design. Despite the common belief that, once production starts, things do not change, one ought to remember that parts are redesigned even after products are turned out. Only during the production process will certain facts become apparent and necessitate a redesign of a part. Mind you, these are minor changes, yet any change will cause problems throughout the production line. The router, or whoever does the routing work, must then make all changes on records, blueprints, part numbers, engineering specifications, process changes, and retooling assignments. The paper work involved in a change is so extensive that the routing section of the production control department is busy throughout the model year with all sorts of revisions.

Once a change is deemed necessary, the question that arises is when it should be introduced. It is up to the routing section to find the opportune time and introduce the change without too much fuss and trouble. Once parts are made, it is usually inadvisable to junk a batch of parts en route to the plant. Hence, when a new schedule or production release on a part is made, the vendor is notified of the change and supplied with the new blueprints, new engineering specifications, and all pertinent information. Of course, the change materials must be prepared and mailed to the supplier by the routing section sufficiently ahead of time that the supplier has a chance to retool and make the necessary production changes before the effective date of the change.

An actual change from one part to a remodeled part must be carefully recorded. It is important to register the serial number of the last unit which still contains the old part and that of the first unit equipped with the new part, because the proper replacement of that part will depend on the serial number. Unless records are kept of when the change was put into effect, dealers or the manufacturer himself will use the wrong replacement part. It is apparent that, in order to avoid later mixups, even a minor change will have to be recorded in diverse catalogs used for replacement, in various purchasing departments, in production shop records, and on blueprints.

No matter how minor the change, it will cause a whole series of problems which must be solved by the production control department. The setup men must be sent out to the shop to the specific work station where the design change necessitates adjustment of tools, gages, and fixtures. It is understood that the change is to be made in such a way that operations are not interrupted. If the company runs on a two-shift basis, the setup will likely be scheduled during the night when the machine is down. Hence, by the time the first shift starts the following morning, the production line is again ready to operate. By that time, the work station must also be supplied with the appropriate material.

It is also the duty of the router to inform the foreman of the change and supply him with the changed blueprints and specifications sufficiently ahead of time to give him a chance to study the change and be able to explain it to the worker involved. Workers usually perform their daily chores without much thinking, and it is up to the supervisor to call any change to their attention and provide the necessary training and explanation.

Furthermore, the change is bound to cause alterations on the bills of materials and parts lists. All these must be made so that everything is orderly despite the necessity for making these changes. Because even in continuous production there is never an absolute freeze of design, the routing function is never obliterated.

SHOP SCHEDULES

Despite the fact that in continuous operations hundreds of machines might be involved, scheduling production is a rather simple procedure. This is so because the production line is already so perfectly synchronized that for any practical purpose it can be considered as one single machine. The same thing is true as far as sub- and feeder-assembly lines are concerned. In other words, we would consider the final assembly (even though in reality it is a large group of interrelated machines) and the various subassembly lines as single machines. It is mainly essential to determine the hours which the line must run to produce the output required by the sales forecast. Once this figure is arrived at, the production authorization consists of transmitting "run" sheets to all foremen concerned with the interrelated subassemblies, feeder assemblies, and the final assembly. If they run the respective lines as required, everything is bound to turn out according to schedule. Actually, the scheduling of a continuous operation resembles the scheduling of a job shop in that the same Gantt chart can be used. Whereas in the machine shop the Gantt chart was used as a machine load chart, in continuous production it can be employed as an assembly load chart. The horizontal lines on the Gantt chart would represent assemblies instead of machines.

If the sales forecast for the 3-month period calls for the number of units listed in Table 13-3 in the first, second, third, and fourth weeks in January,

TABLE 13-3

January	Weeks	Remarks	February	Weeks	Remarks	March	Weeks
960	I		900	I		600	I
860	II		680	II		600	II
1000	III		700	III		550	III
960	IV		800	IV		550	IV

February, and March, then it is the duty of production scheduling to so allocate the assembly departmental time, that is, capacity, that a *relative* continuity of flow is guaranteed if continuous flow is not feasible. If the weekly output capacity of the final assembly line is 480 units per shift, that is, 960 per two shifts and 1440 per three shifts, it is obvious that the number of hours worked on each shift must first be determined. Let us assume that the subassembly lines B, C, D, and E meet the final assembly A and production capacities are as follows: B = 960 per shift, C = 480 per shift, D = 1140 per shift, and E = 480 per shift. Since the subassemblies are usually balanced with the capacity of the major assembly, the final assembly in this case usually requires two pieces of part B, one piece of part C, three pieces of part D, and one piece of part E. The product is the composite shown in Fig. 13-3 plus some other parts which are purchased from outside suppliers. In other words, before final assembly A can take place, production control must see to it that vendor items arrive at the plant; otherwise, B, C, D, or E cannot move through the subassembly line to meet with final assembly A.

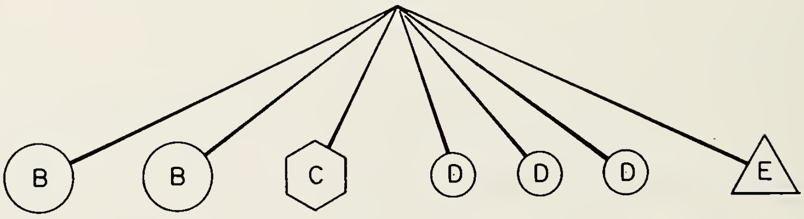


FIG. 13-3

At the risk of oversimplification, let us assume that the lead times for all purchased parts which make up subassemblies B and C are 10 days and 20 days for D and E. (This, of course, would seldom be the case, since each supplier has his own lead time.)

On the basis of the above information, let us see how schedules are developed. The student should be reminded that the schedule here being set up is not necessarily the costwise best schedule. The main purpose is to illustrate the process of arriving at a feasible master schedule on the one hand and subordinate schedules on the other. It should also be remembered that the master schedule itself is not something very rigid, and it might undergo several revisions before the 3-month period is up. To avoid the complicating element of a dynamic industrial setting, let us keep both schedule and business conditions constant.

To illustrate the schedule which we develop, let us use a Gantt chart in the same manner as we used one in job shop scheduling, Fig. 11-6. The horizontal lines will represent the various subassemblies as they are related to one another. The Gantt chart might be so designed that the three shifts can be illustrated on it.

To simplify things, we must ignore one more factor: the time lag between sales forecast requirements and production. January sales are conceivably produced a month or so ahead of time. To achieve stability—and, particularly, continuity of operations—the master schedule might be set up on the main assembly line as shown in Table 13-4. Although we could arrange for one full shift and one half shift, it might not be possible to call in people for a half day and let them go home 4 hours later. Probably the production line must be so arranged that fewer people will be called in on both shifts than normally. According to preliminary plans, in the third week in February, one shift is completely eliminated. This would mean that those on the second shift must be laid off. Let us pause here a minute and look at the validity of the present schedule in terms of market requirements.

TABLE 13-4

January			February		
Week	Production	Shifts	Week	Production	Shifts
I	960	2	I	960	2
II	960	2	II	960	2
III	960	2	III	480	1
IV	960	2	IV	620	*

* At this point the scheduling procedure becomes problematic from the practical point of view.

To see whether the sales forecast and the master schedule agree, it is essential to compare the projected cumulative totals produced by the master production plan with projected sales requirements. Let us start with January, Table 13-5. So far so good. The cumulative totals produced with the master

TABLE 13-5

Sales Forecast	Cumulative Totals	Master Schedule	Cumulative Totals
960	960	960	960
860	1820	960	1920
1000	2820	960	2880
960	3780	960	3840

plan indicate that production runs are always a bit ahead of sales possibilities. In other words, the master schedule for January and the first two weeks in February provides both stable employment and coverage of consumer demand. The question of storage cost must still be carefully investigated, but as we stated previously, the element of cost of storage will be neglected. It should be remarked, however, that this would ordinarily influence the production decision only if it caused some out-of-pocket costs. Let us now develop the February production program on the basis of the sales forecast.

The February master schedule (a part of the master plan) requires quite careful contemplation. As we stated previously, we cannot neglect certain factors, such as that we do not want to lay off people because unemployment funds might be used up and because a lack of employment stability might adversely affect the unemployment insurance premiums. The various fringe benefits can, in the case of layoffs, also cause serious problems and annoying bookkeeping work. We can conceivably avoid all these troubles by reducing overall employment for everyone from, say, 40 hours to 30 hours per week. By doing so, the question of seniority, which often complicates layoffs, can largely be avoided. The February situation might now look as shown in Table 13-6.

TABLE 13-6

Sales Forecast	Cumulative Totals	Remarks	Master Schedule	Cumulative Totals
	3780	Jan.		3840
900	4680	Feb.	960	4800
680	5360		960	5760
700	6060		480*	6240
800	6860		?	?

* One shift.

Another alternative would be to spread the work so that, throughout the month of February, less than 40 hours per week will be worked on each shift yet projected sales will not be neglected. In other words, we want to make certain that production covers market demand even though we are manipulating the working hours in such a way that the limited demand relative to the capacity of two shifts does not cause substantial unemployment to any one group. There might be a few hours of income loss per week on each shift. Another solution might be that a holiday falls in one of these weeks; the labor contract might require that the company give seven paid holidays a year. Why not pick Washington's birthday as one of them? These are the ideas with which the production planner must work until he finds a feasible schedule which will keep the overall costs of production down yet satisfy the requirements of the sales forecast.

To get the most satisfactory solution, the January-February part of the master schedule has been worked out so that each shift works only 36 hours per week during the first and second week of February, a normal two shifts minus Washington's birthday in the third week, and a 36-hour fourth week. Although in this program, Table 13-7, there is still an inventory accumulation of 340 pieces, the schedule appears feasible. As far as the inventory accumulation is concerned, the question that arises is how much it will cost the company to carry extra inventory and how much dollar value is being placed on safety. In other words, a sudden upsurge of demand should not catch the company flat-footed. Since the master plan is formulated ahead of the sales period as well as the manufacturing period, modification might be necessary. But, for the time being, this is the plan. Notice in the February schedule the cumulative totals of sales and production figures balance so that production is always a few pieces ahead of predicted demand.

TABLE 13-7

Sales Forecast		Cumulative Totals		Master Schedule
		Sales Forecast	Production	
January	960	960	960	960
	860	1820	1920	960
	1000	2820	2880	960
	960	3780	3840	960
February	900	4680	4704	864
	680	5360	5563	864
	700	6060	6336	768
	800	6860	7200	864

As far as the master scheduling of the hypothetical company's operations is concerned, March becomes a problem month. There is too much to do for one shift, but two little to do for two shifts. The question is therefore how employment can be maintained without accumulating inventory and while keeping the production line in reasonable balance for most efficient operations. The multiple nature of the various possibilities makes it difficult to answer the question without recourse to cost figures, pertinent sections of the union contract regulating seniority and work week (layoff procedure, how many hours must be paid if employees are called to work, etc.), and other factors affecting operating costs (overhead, inventory, shift efficiency, and shift-pay differential).

It is assumed that the student gained an understanding of scheduling, particularly that it is not a mere division of the man-hours of labor needed to accomplish production goals in light of projected sales, but is instead a careful allocation of working hours of the production line. Costs and savings must be considered, yet the continuity of the production flow must be maintained. From the point of view of production costs, continuous flow is evidently the most efficient kind. Despite its efficiency, it would not make sense to produce unless sales warranted operations.

In view of the limited sales, the March schedule must be so set up that the accumulated inventory is used rather than have a new inventory buildup take place. Thus, the arrangement for March shown in Table 13-8 seems to be feasible. It was evidently impossible to maintain two-shift operations in March; hence, the second shift had to be laid off. According to this plan, at the end of March, the inventory was liquidated; as a matter of fact, the production schedule falls 40 pieces short of the projected sales volume. Since the schedule came out so nicely and production of 40 pieces amounts to less than one day's production, overtime work, Saturday production, or some other arrangement might remedy the situation if sales demand it. The master schedule for the final assembly during January, February, and March is then as shown in Table 13-9.

TABLE 13-8

Week	Schedule	Cumulative Totals	
		Sales Forecast	Production
I	480	7460	7680
II	480	8060	8160
III	480	8610	8640
IV	480	9160	9120

TABLE 13-9

January			February			March		
Week	Production	Shifts	Week	Production	Shifts	Week	Production	Shifts
I	960	2	I	864	2*	I	480	1
II	960	2	II	864	2	II	480	1
III	960	2	III	768	2†	III	480	1
IV	960	2	IV	864	2*	IV	480	1

* 36 hours each. † 40 hours each minus one paid holiday.

Once the master plan for final assembly A has been decided upon, the planner focuses his attention on the various subassemblies and feeder assemblies. These must be synchronized with the main line. When the capacities of these lines are given, a feasible schedule for each line producing the subassembly item can be readily developed. Since subassemblies are gaged to the needs of the final assembly, we are no longer concerned with the sales forecast and its cumulative total, but with the *cumulative total* of the *final assembly* *line.* We must produce each part at the same rate or faster than the flow of the final assembly warrants. Again, the planner must be careful that he does not produce too much of any part or component ahead of time because of the storage and related expenses. Since this procedure is exactly the same as the one just described, at this point, no further explanation is warranted.

The subassembly lines, however, cannot usually operate unless all vendor items arrive in time. Again, none of the vendor items should arrive too far ahead of time because of storage and other related problems. If the item is bulky, probably only a day's or a half day's supply may arrive at a time. Hence, schedules must be worked out so that the arrival of the item is always under control.

Calendar dates must be given to the suppliers. If the suppliers of items which make up the product of the subassembly have 10 days lead time, weekly arrivals must always be scheduled with that in mind. Items going into subassembly lines D and E should be ordered 20 days ahead of time to make sure they arrive 20 days later when needed.

The 10 or 20 days lead time might, of course, be higher if the company wants to keep a safety quantity of, say, 2 day's supply. Thus, the 10 days might become 12 days. The master schedule and all subsequent schedules will permit working out a series of schedules and release dates for suppliers of purchased items. If the lead times are reliable and strikes or other unforeseen happenings do not interfere, the continuity of operations seems to be assured by the master schedule.

DISPATCHING AND "DIFFERENCE" CONTROL

Once the master schedule and all subsequent production schedules derived from it are established, there is no need for dispatching in the ordinary sense of the word. The run sheets submitted to operating personnel are adequate to authorize production. In many companies, the master schedule (or the various manufacturing schedules) are turned over to operating management, who take it from there and make the necessary arrangements (inform employees about shift arrangements, starting times, weekly working hours etc.). The turning over of the schedule automatically issues the production authorization as indicated on the schedule. When the master plan and all subsequent manufacturing schedules are changed because of marketing difficulties or because sales run ahead of expectations, the revised sheets (run sheets) or schedules are turned over to operating personnel. The latter automatically cancel the previous production plans and indicate the new ones.

Dispatching is not quite so simple in companies where the product mix must be under control. It was stated earlier that practically no company is a "pure" production shop manufacturing a single standard item. Hence, the same production line will turn out—mind you, with the same production process—several "different" items. While a two-door sedan and a four-door sedan might be identical in many respects, there are significant differences which the workers on the assembly line must consider. First of all, the frames for the cars are different; secondly, the doors are more numerous in the four-door sedan; thirdly, the front seats are different. Otherwise there is probably no difference between the two cars. A deluxe model will differ in a similar manner from the standard model. The differences are minor, but the fact that they are present requires extra care on the production line. The main function of production dispatching in continuous production is, therefore, to worry about these minor differences and notify either the production foreman, or the production employee himself sufficiently ahead of time to take care of the differences. In that sense then, the production dispatcher does something quite similar to what the job shop dispatcher does.

The job shop dispatcher gives the authorizations via the *order number* and *part number*. The dispatcher in continuous production uses the *serial number*. In the automobile industry, for instance, the motor has its own serial number which might be, and usually is, different from the serial number of the automobile as such. If different components go into the motor assembly, the dispatcher on the motor production line uses the motor's serial number to inform the workers involved; when differences on the car must be considered, in addition to differences in the motor, the serial number of the automobile must be given.

While the name given to the production control work in continuous production is flow control, the latter is—if a minor variation is connected with the flow of production—always associated with *serialized control*.

Flow control is a function of the scheduling group; serialized control is more or less that of the dispatching group. This, of course, assumes that the production control department is divided into routing, scheduling, dispatching, and expediting sections. There is, however, no need for such a fine distinction as far as continuous operations are concerned. The reason is that scheduling and dispatching are in many continuous operations almost identical functions. Take, for example, the case when the schedules (the master and all subsequent manufacturing schedules) are turned over to operating management and simultaneously serve as run sheets. In such instances scheduling and dispatching are done by the same group. Sometimes, once the production line is laid out, the product does not undergo any changes. In that case, there is no need for routing after the original processing and plant layout work has been accomplished.

The dispatcher is important in many types of continuous production because he takes care of last-minute changes not reflected in the master plan or the various manufacturing schedules. Although the producer of TV sets and many other manufacturers do operate in the same manner as the automobile manufacturers, we will consider automobile manufacturing because the student might be more familiar with it than with any other production process. The dealers might have asked for a large number of standard gear shifts. If the sales forecast misjudged the consumer desires and scheduled production of more fluid drives, there is a bottleneck in production. The work station where the drive shaft is placed into the automobile may very well be shy of the specific drive shafts. To prevent production from stopping, the dispatcher must decide what kind of cars to make now with the available parts to keep things moving. The dispatcher has, in most companies, been accorded by line management a considerable amount of authority to use his judgment. Unless this latitude is given to him, production could stop without warning. Management therefore realizes the shortcomings of the forecasting procedure and lets the dispatcher rectify things right on the production line. It is true that cars are being produced for which little or no call is made, but it is better to operate in this manner than to stop and wait until the appropriate parts arrive. It is safe, however, to produce tomorrow's cars today.

The dispatcher is, of course, familiar with consumer preferences and is always informed about the general nature of sales. He knows the colors which are preferred by the buying public, the two-tone combinations generally favored, etc. Hence, if certain parts are short, he knows which parts to build into the cars to meet with an adequate reception on the market. The delay in the arrival of parts is probably not more than a half day or so. Therefore, he has ample time to make up the discrepancy between dealer requests and production rate requirements. It is essential, however, that he make a good guess and in the meantime produces those automobiles which would be ordered by subsequent customers (dealers) anyhow. In other words, he makes items ahead of time in the hope that orders of specific colors, transmission, motor type, and two versus four doors will rectify his decision under the extraordinary circumstance. When the missing parts arrive, he will keep feeding through all those cars which he was forced to defer because of missing parts.

One should realize, of course, that some degree of bunching would go on anyhow. Dealers might request different colors all the time; dealers might order one kind of transmission in the morning and another type in the afternoon. The requirements keep varying. The dispatcher's office tends to accumulate dealer requests and, when a sufficient number of items of identical specifications are accumulated, the whole group is sent through the line at once rather than have type A follow type B to be followed by type A again. The dispatcher accumulates 50 or 100 A's and only then does he run through all the B's.

By now, the student must have noticed that we are almost back to repetitive production. While the production flow is still continuous and is kept moving, the serialized control helps to keep things apart without interrupting the flow, despite the differences which the manufacturer must build into the product. Without a dispatcher, the production line could not operate in this manner and we often would have to resort to repetitive techniques of production. And, as is well known, continuous production is considerably more efficient than repetitive production.

It should be remarked at this point that in some plants where no variety is built into the product, dispatching consists of turning over the run sheets to operating personnel. In other words, scheduling and dispatching are pretty much the same kind of activity.

EXPEDITING

We recall that, despite the excellence of order control, expediting was important in job shops to push orders through the plant, because delays in production will always occur and expeditors help foremen get orders out. But in mass production the production line moves almost by itself. Thus, we should find out why expediting is necessary in mass production at all.

During production, it is scheduling which assures that everything clicks. Prior to production, it is up to the plant layout engineers to balance output capacities of subservient departments with that of the major assemblies or key machines; it goes without saying that the subassembly stations are equally synchronized with the final assembly line. As far as operations are concerned, it seems that lack of consumer demand or major breakdown are the only factors which could disrupt the continuity of operations. Nevertheless, there is another factor not to be neglected, namely, that the continuous producer does not depend entirely on his own resources, but depends largely on arrival of materials. Hence, expediting in mass production is restricted almost exclusively to tracing shipments.

If raw materials do not arrive as they are supposed to, the whole production line must be shut down because of lack of material. Although occasionally it is possible to bypass certain work stations where a part is missing and work around the work station through all sorts of improvising, in most cases missing parts or components will prevent the whole line from moving. Hundreds of people might have to be sent home.

In view of the magnitude of the problem, management wants to know when the vendor's shipment was made and by what carrier. It often becomes necessary to make special arrangements to get certain badly needed shipments into the plant. Occasionally, the arrival of the shipments to the plant must be prevented because a sudden change in the production schedule no longer requires the arrival of a part or component at the anticipated time. The longer the shipment is underway, the less worry the company may have with storage and handling of the materials. Occasionally, arriving materials are not unloaded but are instead left in temporary storage right in the railroad car because the demurrage charges are comparatively small. Thus, expediting is concerned not only with getting materials into the plant but with keeping them out until needed.

In the case of an automobile plant, where output is relatively large and the rate of output is steady, it would be difficult to have too many parts arriving too far ahead of time. Here, it becomes a masterpiece of planning to arrange arrival of thousands of parts so that they can enter the production stream within a few hours after they have entered the receiving section. The parts and components must therefore arrive practically at the same rate as production uses them up.

By comparing the dispatching and expediting functions of continuous production with those of job shop practices, the differences and similarities become apparent. In both instances, orderly flow of production is the aim, but the means and practices to attain orderly flow will tend to be different. In continuous operations, the problem of flow is a matter of tying in the suppliers' and the common carriers' operations with the operation of the production line. The internal flow of production is a matter of balance between output of interrelated work centers (assembly versus subassembly) which is built right into the plant layout; the flow then depends largely on the arrival of materials and proper maintenance. If many stock items are used, flow also depends on the excellence of inventory control. Therefore, the continuous producer has a large maintenance department with the duty of preventing machines from breaking down (preventive maintenance) and a well-organized inventory control department. Since the internal synchronization is a technical-mechanical problem rather than a production control function, attention must be focused on the expediting as far as material availability is concerned.

MATERIAL ARRIVALS

Scheduling in mass production is divided into two basic parts: 1) master scheduling of output of the plant (company) as a whole and 2) scheduling the output of the subsidiary plants, sister plants, suppliers, and subcontractors so that they are all geared to the output of the company's end product. This, as has already been stated, is done with due regard for the individual suppliers' lead times. Depending on the reliability of the supplier or the common carrier which transports the goods from the suppliers' plants to the production site, the company would also keep a certain quantity in stock or in temporary storage (in bank) to mitigate the effects of delay which may never be completely eliminated. How much the company keeps in stock will be discussed subsequently. Generally speaking, the main plant will tell the supplier (whether a subsidiary plant or an independent supplier) the quantity needed and will give release schedules against the total quantity as required by the scheduled production runs. Since the supplier is usually (but not necessarily) supplied with tentative master schedules and forecast sales figures, the plant's own production control department can make preliminary plans. Although the suppliers are not authorized to produce anything until the release schedules are out or other authorizations are given, they can prepare for the size of the order in advance. Thus, the central production control agency is relieved of a great deal of the problem because the plant's production control group takes over from here on.

ROLE OF INVENTORY CONTROL

It must be apparent that perfect synchronization of arrival of materials is impossible and that decisions must be made on how much safety quantity should be on hand at all times so that a delay will not catch the company empty-handed. Although the production control department will direct the movement of materials in light of the production requirements, ordering is often done not by the production control department but by the inventory control group. This is the case with stock items. In this case, production control operates under the assumption that the inventory department will assume the responsibility for directing the movement of materials to and from the stockroom but not to the site where materials are needed. Production control merely tells the inventory group—unless it happens automatically since everybody concerned may get a copy of the output quantities scheduled—what is needed and when things are needed. It is the function of inventory control to assure the availability of materials based on the given rate of use, the supplier's lead time, and the safety quantity which is kept above and beyond actual needs. In addition, the inventory control will work together with purchasing; and orders, when released, will be economic lot quantities rather than the smaller and more costly broken lots.

In this sense then, production control will merely inform the inventory control group about the rate of use of given materials; and from there on, it is up to the inventory group to make sure that materials are available when needed. That the best assurance is large safety quantity is evident, but, of course, it is one of the functions of the inventory control people to assure availability of needed parts and components, yet keep the inventory carrying charges and costs at a minimum. More details will be given about this in Appendix F. At this point, it is essential to remember that whereas inventory control worries about the arrival of materials, production control merely gives the rate of use quantity. The storage function is in other hands.

SUMMARY

LARGE-SCALE CONTINUOUS PRODUCTION

Large-scale production is possible because the sales volume is large enough to warrant high-speed expensive equipment. The trouble with the sales volume, however, is that it is not easily divisible into equal rates of sales throughout the year. Consequently, it is difficult to maintain a continuous use, that is, an even use of the costly production equipment. But high-speed production equipment can pay for itself only if it is in continuous use. Therefore, the task of production planning in general, and of production control in particular, is to maintain or devise a method which keeps production equipment in use as continuously as is consistent with financial aims of the company despite a fluctuating demand.

Continuous production can be profitable if and when the company is able to sell at competitive prices and when it is always in a position to provide consumer's needs when those needs arise. These are not necessarily compatible aims. Fluctuating demand requires availability at any time, but what should a plant do if demand at any given time exceeds the output capacity of the plant? This is where production control enters the picture. The production control department must apportion equipment capacity in such a manner that peaks and valleys of demand are eliminated and that the plant produces at a relatively even rate, but without overtaxing (both financially and otherwise) the inventory control department as far as raw materials (components) and finished stock are concerned.

Production Planning in Continuous Operations

The planning process can be divided into the determination of the product, process, and plant design on the one hand and the master production plan on the other. Although the customary dispatching and expediting operations are still prevalent, the customary production control functions here assume a somewhat different meaning. The same thing is true as far as the routing function is concerned; in its original meaning it is not needed. Nevertheless, all functions of production control—routing, scheduling, dispatching, expediting—are present in continuous production.

Plant Layout and Routing

In continuous production the route is built right into the production line; therefore, routing loses its customary meaning. Since we deal with one standard product moving down a production line, constant development of alternative routes is not necessary. Of course, if there is a design change, it will precipitate many changes in record keeping, specifications, and instructions which would ordinarily fall within the jurisdiction of the router. These functions, in this type of operation, are also retained by the router. Process and plant layout design tend to replace the routing function, however.

Scheduling and Inventory Control

Scheduling in continuous production involves several problems, but in the main it centers around building a production program capable of supplying the market with the right quantities of goods needed, at any given time, without overtaxing the inventory control function. Here "overtaxing" refers to costs rather than to the burden of added work.

Inventory control and production control must, in such operations, go hand in hand. The production schedule must evidently take the inventory problem into consideration. Thus, too much cannot be produced ahead of time just to keep equipment in continuous operation if the cost of storage, including the carrying charges, would far exceed the savings attainable from the continuous use of equipment. By the same token, it is essential that the continuity of production flow is maintained, which requires the storage of components and raw materials always in sufficient quantities as to never run out of materials when production requires them. Again, a happy compromise must be made in order to have the cake and eat it too. Stock must be kept at a minimum, without taking too much chance that a lack of materials will prevent the continuous flow of operations. This is basically a cost problem which can be solved by production control and inventory control departments through a close cooperation.

MASTER SCHEDULING AND FLOW CONTROL

The master schedule is a plan established on the basis of expected sales (sales forecasting) and matching of plant capacity with production and sales requirements. If demand is greater than output capacity, it is evidently necessary to produce ahead of time and stockpile. By careful master scheduling, plant operations can be kept continuously busy, and the arrangements made with suppliers, subcontractors, and sister plants might be of considerable importance in keeping up a continuous flow of production.

The fact of the matter is that in continuous production, raw materials and components must arrive at the same or nearly at the same rate as production uses them up. In order to organize and assure the continuous arrival of materials, it is essential to know the master plan. The master production schedule is, then, the basis for flow control, that is, also making the subcontractors conform to a predetermined production program.

QUESTIONS

13-1. What is the basis of production scheduling in continuous production?

13-2. In continuous production what is the relationship between plant layout, process engineering, and routing?

13-3. How, if at all, is inventory control related to production scheduling in continuous production?

13-4. What is involved in master scheduling?

13-5. What is meant by flow control or serial control and what is the difference, if any, between the two above concepts?

13-6. What would a continuous manufacturer do if demand consistently exceeded output capacity?

13-7. Explain the methods the continuous manufacturer can employ to adjust his output in light of changing consumer demand.

13-8. How are mass consumption, mass production, and competitive pricing related and how can the continuous manufacturer bring all these factors to a common denominator?

13-9. What is "float" and to what extent is this concept important in continuous operations?

13-10. What is meant by "lead time" and what importance is attached to it in scheduling operations in continuous manufacturing?

13-11. What, if any, relationship is there between inventory control and flow control?

13-12. To what extent is the routing function important in continuous production?

13-13. What importance is attached to dispatching in continuous operations?

13-14. If operations are based on a constantly moving conveyorized production line, what significance can be attached to expediting in continuous manufacturing?

13-15. To what extent are continuity of production flow and the costs of production related to one another in large-scale mass production?

PROJECTS

13-1. Contact a mass producer engaged in continuous operations and ascertain his master scheduling procedure. Subsequently, determine 1) the extent to which the product is standardized and 2) the sales volume, including the seasonality of sales. Based on the information thus gathered, criticize the company's master scheduling procedure.

13-2. Describe the prerequisites of continuous production.

13-3. To what extent does continuous-type production lend itself to automatic production? Give the limitations as well as the possibilities in certain types of industries.

13-4. Determine the design features which the process and plant layout engineers must consider and, in reverse, the processing features which the design engineers must consider prior to performance, or during performance, of their respective functions.

13-5. List a few pure continuous and a few nearly pure continuous manufacturers in different industrial fields.

CASES

13-1. THE PUXLAX CORPORATION

One of the largest producers of sink waste-disposal units, Puxlax Corporation has been caught in the cost-price squeeze. Although sales have been rising even during the recent recession years, profits on sales have been progressively smaller. While this is customary nowadays in the industry, it is more serious as far as Puxlax Corporation is concerned because waste disposal units have been the bread and butter of the company ever since its beginning after World War II. As a result of important patent rights, the company achieved a considerable reputation in the electrical appliance business. However, the best-known product Puxlax sells is the waste-disposal unit, which accounts for over half a million units per year. Other electrical appliances represent a relatively small portion of the company's profits.

These waste-disposal units eliminate one of the most unpleasant chores in housekeeping by chewing up waste food in the kitchen sink and thereby eliminating the garbage can, burning the garbage, or disposing of it in some other onerous manner. The popularity of the Puxlax waste-disposal units began with the slogan: "Husband, don't be a garbage man, buy a Puxlax waste-disposal unit."

The waste-disposal unit is a device which fits into the opening of any kitchen sink, which may be from two to four or more inches in diameter. Its function is to dispose of kitchen waste by pulverizing it and letting it go down the drain with cold water. When installed by replacing the ordinary drain fitting with a Puxlax drainage section, a unit can be installed below the kitchen sink. Waste-disposal units dispose of garbage by forcing the waste against a grinding ring in a shredding chamber. This procedure takes only a few seconds. Thus, with water, the food particles disappear from the plate and literally go down the drain.

Generally speaking, the company sells to first users, because the life expectancy of the disposal unit is quite high. The replacement market will begin around the middle of 1965. There is little need for repair except that possibly the blade must be replaced periodically, for someone may throw a piece of metal into the unit, which can easily cause breakage. Excessive running of the unit may also help to burn out the motor. Generally speaking, however, waste-disposal units remain virtually troublefree garbage disposers for many years and will absorb corncobs, vegetable peelings, fruit parings, rinds, eggshells, small bones, tea leaves, and coffee grounds—in short, everything which can be ground or shredded in tiny pieces.

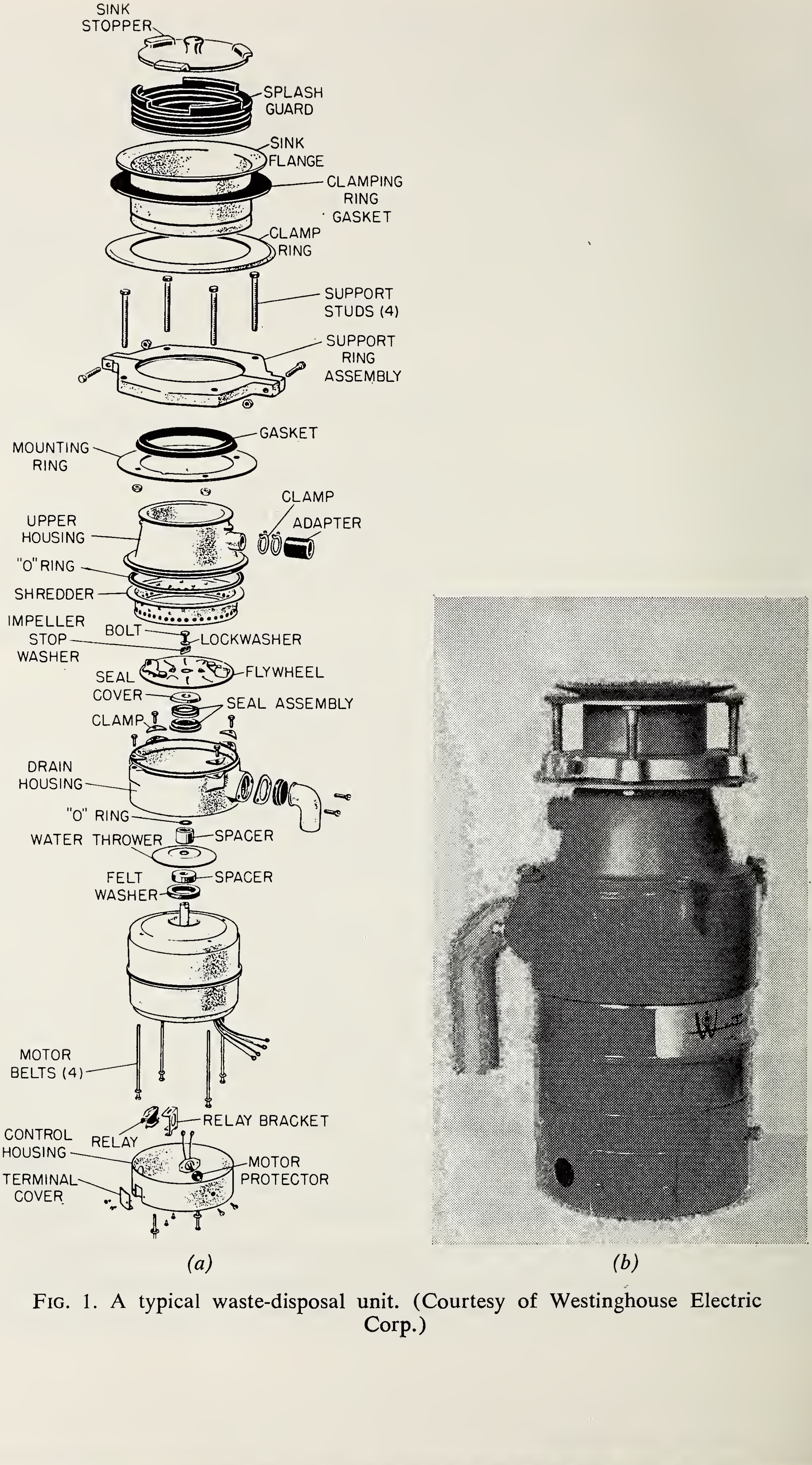
The Puxlax Corporation produces basically two product lines, but it sells 75 different combinations of the same products. Different attachments, components, and capacities must be assembled with the product according to customer's specifications. These changes are mostly in sizes of sink openings, pipe extensions, drainpipe diameters, and sink traps, but they can be more significant changes such as differences in motor size, horsepower, voltage, and current; size of food-container unit; and blade quality and size. Because of the variations which must be built into the product, model prices vary from $50 to $150.

The continuous-feed models grind the food wastes as they are scraped into the sink; cold water and the motor run while the waste is consumed. Batch-feed models dispose of single loads one by one. The switch is combined with the drain plug. After the disposer is filled, and its top is plugged, it begins to consume the load. When it is reopened and refilled, it will chew up another load of waste.

The description of the waste-disposal unit is given merely to indicate the manufacturing problem in adhering to customer's specifications while selling the disposal units at competitive prices. A typical waste-disposal unit, manufactured by Westinghouse Electric Corporation is shown in Fig. 1 in which illustration view (*a*) is an exploded drawing of the unit and view (*b*) is a photograph of the unit. The fact that there is excess industry capacity puts a pressure on prices, but the main problem the company encounters is the foreign waste-disposal unit which sells at considerably lower prices than the Puxlax units. Of course, the Puxlax units are custom-built, while foreign waste-disposal units are made only for standard sink openings.

Intensive cost-reduction programs have helped in cutting the costs of production, but constantly rising costs and competitive pricing tend to reduce company profit margins. While on the waste-disposal units which sell for standard sink openings, electric current, and normal home requirements price reductions have amounted to 20 to 28%, the costs of castings and other foundry products, finished steel, and controls used and bought from the outside have gone up 26, 24, and 25%, respectively. And on the average, wages and salaries, including benefits, have increased 31.6% since 1955. While the average wage rate at Puxlax is $2.50 per hour, the West German and Japanese waste-disposal manufacturer pays less than 70 cents per hour. Thus, price competition is extremely severe in certain product lines. Quality-wise, Puxlax units are far superior to any other, but customers tend to look at the price. Therefore, in order to maintain sales, prices had to come down, but costs could not be held down despite the extensive work simplification programs which were first introduced in 1962.

Since cost reduction can be attained only through productivity increases, the company contemplates a new production control system which would permit production of different units according to customer specifications without interrupting the flow of production. It is estimated that assembly costs per unit of output could be cut by 50%. Furthermore, operations could be conveyorized, which would further help in maintaining a high rate of output.



(a) *(b)*

FIG. 1. A typical waste-disposal unit. (Courtesy of Westinghouse Electric Corp.)

If successful, competitive prices could be attained without sacrificing either quality or profit margins.

To accomplish this, the production control department advanced the proposition of 1) centralized production scheduling throughout the plant, 2) determination of minimum and maximum levels in the inventory setup and giving blanket authority to the inventory control department to write out direct production orders when the minimum was reached, 3) determination of economic production lot quantities which would be connected with the point made above, and 4) giving dispatch orders not to the foreman but directly to the worker from the production control department.

The description of the proposed method will be intermingled with the current practice to indicate the nature of the proposed changes. Thus, the nature and extent of the change can be seen.

In the past production requirements were developed from sales records kept in the office and orders which came in from dealers. The orders from dealers indicated the type of unit, batch feed or continuous feed, in addition to listing the various special attachments needed. Since customers had different power supplies (direct or alternating current, 110 or 220 volts), the motor requirements might differ, and this was particularly true of export items. The drainage section, sink openings, drainpipe diameter, and sink trap were invariably different, and it was the task of production management to produce the items to customer specifications. The capacity of the batch-feed models differed according to customer needs and could vary from a pint to a considerably larger size. With these differences in size went differences in motor size and blade velocity, causing dozens of other assembly changes and parts requirements.

Sales records indicate that on the average about ½ million units are sold per year and the master schedule was set up on that basis. The master schedule has broken down the sales requirements into two-thirds of batch-feed and one-third of continuous-feed models rather than into actual units according to size, attachment, and other special requirements. Therefore, the production control department's task was to make out manufacturing schedules on the basis of this vague requirement.

On the basis of past production and purchasing experience, the production control people worked with 30 days float; in other words, they figured that it takes 30 days from the date of receipt of material until the parts are assembled into waste-disposal units of the required size and type. While purchase lead time differed, the company ordered large enough quantities at rather regular intervals so that the in-stock quantity was usually adequate to carry out normal production within the 30-day period. The purchasing department knew the lead time of each supplier of parts, or that of raw materials. In case usage was greater than anticipated, purchasing usually ordered when the shop reported that "we are running low on terminal *x*, motor *y*, or flat-head screw *z*." There was, however, no record keeping in the stockroom, under the assumption that the cost of keeping records would be greater than the value of the information. Thus, the decision when to reorder came from two basic sources: 1) the records of purchases versus shipments and 2) foremen's reports that they were running low. This system worked in the general but not in the specific sense. The reason was that some parts moved faster than others depending on the type of units customers ordered and on the differences in the attachments which went into the units. To counterbalance this tendency, every half year, the stockroom made a check on inventory by weight count and the purchasing department adjusted its records. Thus, toward the middle or the end of the year it was possible that delays occurred owing to running out of parts and production had to bypass the assembly of given parts. After a few months, things got out of hand again.

The latter situation deserves further explanation. While it was possible to bypass or work around an assembly station, this was costly for several reasons. First, if the part was deep inside the unit, it was difficult to get to it later. Thus, instead of taking ½ minute to place the missing part into the unit, it often took 3 to 5 minutes and even more if disassembly was needed to get to the place where the part belonged. Secondly, the item was stored and tagged and was kept in boxes until the needed part arrived. This usually took at least 2 to 3 weeks and in the meantime units were often lost—not in the physical sense—so that a new item had to be assembled and sent out to the dealer. When the "lost" unit was discovered again, it had to be stored as a finished-unit inventory, and it frequently took several months before a customer called for exactly the same unit with the same specifications. To get rid of the item, it was frequently better to remodel it in the sense that a part was taken off and replaced with another one which the customer desired.

These interruptions in production were reduced, as the years passed, through gradually increasing the minimum in-stock quantities to a 3-week supply. Hence, only items which were relatively infrequently in use ran out of stock on occasion. During the recent efficiency drive, however, it became apparent that the company tied up an unreasonably large amount of working capital in inventory items. This was one of the reasons why the production control department was created and assigned the task of figuring out a better way of production which would reduce the cost of manufacturing, including inventory carrying charges.

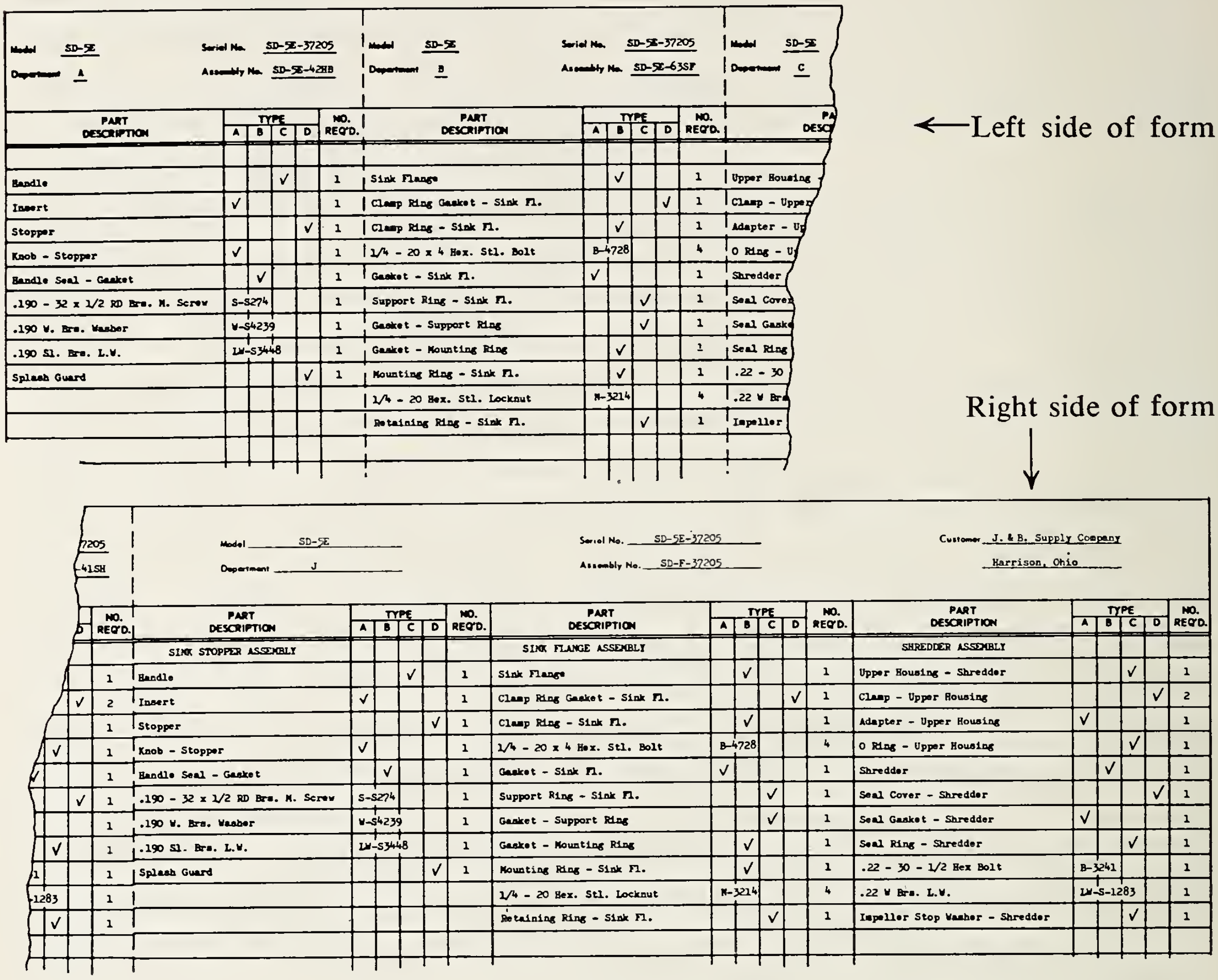
Lead time on Puxlax fabricated parts, depending upon their fabrication process prior to reaching the assembly floor, may vary between 3 and 12 weeks. With company-manufactured parts, there is usually no problem and the plant has a perfect control. Being an internal lead time, in case of urgency, production time can be shortened through a different allocation of available plant facilities in order to accommodate an urgently needed part. Otherwise, the company-manufactured items, which subsequently enter the assembly process in the same manner as the purchased items, are kept in the storeroom and are handled there in the same manner as the purchased items. Either the foreman reports that the item is running low or production control knows from the purchase and/or production records compared with shipments how many parts should still be in the bins. The raw materials used for this purpose are ordered at regular intervals as determined by the production control department and executed by the purchasing group.

The first and major suggestion is that production planning and control will be separated from supervision. In the past supervisory personnel were given a list of items and attachment requirements. Each foreman responsible for certain subassembly work did his best to schedule the requirements into his work load and comply with them as best as possible. The name of the dealer and the extra attachments were checked on a preprinted tag. Since on each subassembly not more than 10 items were interchangeably used on different models, the foremen could build these changes into their subassemblies. Nevertheless, these were rather slow processes, because if the part was not frequently used, either the foreman or the employee had to go to the stockroom to get it. The waiting line in front of the stockroom was long, and this was the place where employees had an excellent chance to exchange gossip of the day without being reprimanded by their foremen—they were waiting for a given part. Occasionally an employee had to leave the stockroom area empty-handed because the stock clerk reported that he could not find the item; either he was out of stock or did not know where the item was. One of the main difficulties was that employees did not know the proper names of the parts and called them by names they themselves used. The stockroom clerk did not know the "hicky which goes into the cam facing." Employees often returned with a sample part to show what they wanted, but often that was not adequate information for finding the item. A foreman usually knew the name and the part number by heart and could give the proper name and number; but if he were not available, the employee had to wait until he returned.

In the new system it will not be up to the foreman to fit the various specials into his schedule, but production control will tell the worker exactly what to do. Each assembly will flow directly to the main assembly so that a river-like system is worked out. The tributaries are the subassemblies entering the main assembly. The main assembly will be conveyorized and will move in 1-minute intervals.

The orders received for waste-disposal units will be separated into the two main groups of continuous and batch-feed models as in the past. Then clerks will make out tags on which the standard information will be supplemented by check marks. The tags can be torn apart into 10 pieces where the perforation indicates. The perforated and detached pieces of the tag go to the respective foreman of the 10 assembly sections. Each section of the tag, Fig. 2, carries the same serial number.

Dealers will be supplied with printed forms on which all the standard information will be listed according to parts and part numbers. When a customer wants a given size of fitting on his disposal unit, the dealer will identify the type of waste-disposal unit both by name and style number and check the fitting, capacity, and other design differences with a penciled check mark. This information, when received in the sales department, will be transposed to the tag illustrated in Fig. 2, at the extreme right part of the form without departmental number. These orders will then be organized into units (blocks). If possible, 50 or 100 units of the same kind will go to each foreman. Since things will be planned a week or so ahead of time, the production control department will have a chance to accumulate jobs of the same kind and lump them into a block. A block or a half block is simply a group of orders which carry sequential serial numbers. Actually, this seldom has any significance except that it eliminates the item-to-item changeover. Instead of specifying that a particular part be placed in the



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Model SD-5E
Department A
Serial No. SD-5E-37205
Assembly No. SD-5E-42HB

Model SD-5E
Department B
Serial No. SD-5E-37205
Assembly No. SD-5E-63SF

Model SD-5E
Department C

PART DESCRIPTION	TYPE A	TYPE B	TYPE C	TYPE D	NO. REQ'D.	PART DESCRIPTION	TYPE A	TYPE B	TYPE C	TYPE D	NO. REQ'D.	PA DESC
Handle			✓		1	Sink Flange		✓			1	Upper Housing
Insert	✓				1	Clamp Ring Gasket - Sink Fl.				✓	1	Clamp - Upper
Stopper				✓	1	Clamp Ring - Sink Fl.		✓			1	Adapter - Up
Knob - Stopper	✓				1	1/4 - 20 x 4 Hex. Stl. Bolt	B-4728				4	O Ring - U
Handle Seal - Gasket		✓			1	Gasket - Sink Fl.	✓				1	Shredder
.190 - 32 x 1/2 RD Brs. M. Screw	S-S274				1	Support Ring - Sink Fl.			✓		1	Seal Cove
.190 W. Brs. Washer	W-S4239				1	Gasket - Support Ring			✓		1	Seal Gask
.190 Sl. Brs. L.W.	LW-S3448				1	Gasket - Mounting Ring		✓			1	Seal Ring
Splash Guard				✓	1	Mounting Ring - Sink Fl.		✓			1	.22 - 30
						1/4 - 20 Hex. Stl. Locknut	N-3214				4	.22 W Br
						Retaining Ring - Sink Fl.			✓		1	Impeller

Right side of form
↓

7205
-41SH

Model SD-5E
Department J
Serial No. SD-5E-37205
Assembly No. SD-F-37205
Customer J. & B. Supply Company
Harrison, Ohio

		D	NO. REQ'D.	PART DESCRIPTION	TYPE A	TYPE B	TYPE C	TYPE D	NO. REQ'D.	PART DESCRIPTION	TYPE A	TYPE B	TYPE C	TYPE D	NO. REQ'D.	PART DESCRIPTION	TYPE A	TYPE B	TYPE C	TYPE D	NO. REQ'D.
				SINK STOPPER ASSEMBLY						SINK FLANGE ASSEMBLY						SHREDDER ASSEMBLY					
			1	Handle			✓		1	Sink Flange		✓			1	Upper Housing - Shredder			✓		1
		✓	2	Insert	✓				1	Clamp Ring Gasket - Sink Fl.				✓	1	Clamp - Upper Housing				✓	2
			1	Stopper				✓	1	Clamp Ring - Sink Fl.		✓			1	Adapter - Upper Housing	✓				1
	✓		1	Knob - Stopper	✓				1	1/4 - 20 x 4 Hex. Stl. Bolt	B-4728				4	O Ring - Upper Housing			✓		1
✓			1	Handle Seal - Gasket		✓			1	Gasket - Sink Fl.	✓				1	Shredder		✓			1
		✓	1	.190 - 32 x 1/2 RD Brs. M. Screw	S-S274				1	Support Ring - Sink Fl.			✓		1	Seal Cover - Shredder				✓	1
			1	.190 W. Brs. Washer	W-S4239				1	Gasket - Support Ring			✓		1	Seal Gasket - Shredder	✓				1
	✓		1	.190 Sl. Brs. L.W.	LW-S3448				1	Gasket - Mounting Ring		✓			1	Seal Ring - Shredder			✓		1
1			1	Splash Guard				✓	1	Mounting Ring - Sink Fl.		✓			1	.22 - 30 - 1/2 Hex Bolt	B-3241				1
-1283			1							1/4 - 20 Hex. Stl. Locknut	N-3214				4	.22 W Brs. L.W.	LW-S-1283				1
	✓		1							Retaining Ring - Sink Fl.			✓		1	Impeller Stop Washer - Shredder			✓		1

FIG. 2

501-serial-numbered item and then a similar but slightly different part in the 502-serial-numbered item, the foreman can tell the girl (usually girls are employed) that each of the next 100 units starting down the line with serial numbers beginning with 500 receives cam 775. Actually, the girl could also read the tag, but this method of blocking serial numbers further simplifies supervision and reduces the thinking on part of the employees. At least the employee does not have to think about which part goes into this unit and which part into the next. In our example all units up to serial number 600 get a specific part that will be assembled in a specific manner.

After the production control department separates and organizes the tags going to each foreman, the parts requirement will be taken off and tallied on an *inventory usage sheet*. This will subsequently be used to deduct from inventory records the parts which are being used up in production. As far as the latter is concerned, the inventory control will be placed on a minimum-maximum system based on a well-known formula yet to be established. The minimum is an arbitrarily established figure and represents 5 day's output and 20 days in-bank time. In other words, the company keeps a 25 day's supply at hand. If a part which is seldom used is just about running out, a 5-day delay might occur before its replenishment. Generally speaking, however, it is not expected that the company will too often run out of parts, since the withdrawals will be checked against the inventory records and a shop order or purchase order will be filled out when the minimum is reached. Unless the clerk forgets to take notice of the minimum quantity that becomes apparent at the time of his last disbursal—which is not likely since the stockroom and the inventory control records work individually, and what the one does not notice, the other certainly will—the order will invariably be placed. The order quantity on each item will be calculated according to the mathematical formula:

$$x = \sqrt{\frac{2As}{i}}$$

where x = quantity to be obtained on each order,
A = cost of getting a setup in the shop or the cost of preparing a purchase order,
s = annual usage, in units,
i = annual cost of holding one unit in stock 1 year.

The stockroom will supposedly receive the new shipment just about the time that the stock is low. Thus, neither the foreman nor the employee will ever get into the predicament of finding out at the last minute that stock is running out. The production control department believes that this will remedy the inefficient practice of "working around" a work station because of lack of parts.

The fact that production control and supervision will be separated indicates that the production control department will be accorded almost "dictatorial" power to get production moving. They will program the production from start to finish, and the task of supervisory personnel will be reduced to making certain that production moves smoothly. Unless supervisory personnel make things move, the whole production setup is in jeopardy and everything will stop. The conveyorized main assembly will move, but only if the subassemblies are available at the right time and place and the parts used in the assembly process are *always* available when the worker needs them in the assembly process. Thus, the production control department depends vitally on the inventory control procedure (which is also under the control of the production planning group) and on the skill of the supervisors to get things moving.

Employees cannot leave their workplaces unless the foreman sends a relief worker; employees have to perform the operations within the allowed time; some units must always be kept in reserve just in case a sudden delay might occur and the department does not have any unit which could be placed into the stream of production flow. In return, however, the foreman is relieved of planning duties altogether. The production control department makes sure that he has the parts needed in assembly; the production department also prepares for his daily task and if possible puts identical orders into blocks. Depending on customer requirements, the block might be quite large or quite small. However, the attached tag bearing the departmental number and the various relevant information permits the supervisor to leave his department without fearing that employees will not know what to do. Employees must, of course, be taught to memorize the name and number of the parts which they use and must learn how to assemble a wide variety of different attachments. The latter is not much of a chore, however, since the general shape and form of the item are the same and only the diameter or the dimension might vary somewhat. Of course, a wrong part might fit in a unit just as well as the right part, since the parts assembled are perfectly interchangeable.

The new dispatching system requires special attention, because 10 assembly sections (9 substations) are involved and the work of each subassembly must be coordinated with the final assembly. For this purpose, the dispatcher's office has been equipped with a billboard similar to a football or basketball scoreboard. On this billboard is indicated the serial number which should start down the line. Usually a block is written and a gong indicates the start of a new block number. If a sudden change is given, the gong indicates that all interested parties should pay attention to the scoreboard, as everybody at Puxlax calls it. The function of this centralized dispatching is, of course, to make sure that all related parts of the production system work together. Any mistake here can cause production to stop.

In the new production line system, all work stations will be synchronized. Time studies are available and balancing the production line does not appear to be difficult. The products in the subassembly stations will be moved by hand and those in the main assembly by a conveyor system. The capacity of the plant is not something fixed, since adding employees or laying them off can raise or lower the output capacity according to sales requirements. According to preliminary studies, the production line will move as long as production control, inventory control, and supervision fulfill their respective tasks in the production system. The main thing is that production control accomplishes what it purports to accomplish.

It is hoped that the production flow will be smooth, but if employees influence the flow by laggard production, a group incentive is foreseen for each subassembly. The main assembly should, however, work smoothly without an incentive system provided the conveyor system is capable of forcing its own work pace on the workers sitting along the production line.

Work is performed on benches with hand tools, screw guns, and soldering irons. It is simple hand assembly in most cases, and even crimping connectors on cables requires very little if any skill. Employees are therefore girls who are hired after the state employment service has given them the usual finger dexterity test. The personnel department interviews them, and the foreman decides whether the personality of the girl fits into his employee group. There are currently 40 foremen and 20 assistant foremen. The company hopes, however, that when 20 of the older foremen retire within 1 or 2 years, they will not be replaced. The production control department intimated that the system which is being proposed will require additional production control clerks but will permit a substantial reduction in high-paid supervisory personnel.

Even though the company has maintained its share of the market over the years, it appears likely that any substantial reduction in price will cause a growth in company sales.

Questions. The Puxlax Corporation case indicates the problems which the company hopes to eliminate through the new system of production control. Although not essential, the student could set up the formal pattern of analysis just to see whether or not the new plan of production control seems to be adequate to accomplish what it purports to accomplish. For this reason, state the symptoms on the left-hand side and the causes on the right-hand side of the same sheet of paper.

1. What would you suggest the company do to eliminate the causes of those symptoms? Compare your suggestions with the plan contemplated by the company.
2. If you find fallacies in the company's plan, suggest ways to eliminate them.
3. Do you think that the proposed production control system will actually cut the costs of the company—other than the material costs—by 50%?

4. Calculate the storage costs by making certain assumptions under the present method of inventory control and under the contemplated method of inventory management. Is there any saving involved without adverse effects on production?

5. In which way will the new production control system reduce the labor cost?

6. The company produces custom-built waste-disposal units. How in this case is custom building compatible with continuous production?

7. Pass judgment on the form developed by the company to inform foremen and operators as to which part should be assembled into the subassembly or finished assembly.

8. Criticize the production control department's method of blocking serial numbers and dispatching individual orders.

13-2. THE CLEVELAND ELECTRIC ILLUMINATING COMPANY

The company was incorporated in 1892 as the Cleveland General Electric Company and acquired the properties and business of two firms which had been producing and selling electric energy since 1881 and 1884. In 1894, the name was changed to its present one. The company's expansion through acquisition of smaller power companies and building its own power plants in the Cleveland area resulted in a network which services a sizable area along Lake Erie and in the vicinity of Cleveland. In 30% of the area of municipal Cleveland, the company competes with a municipally owned power system. In 1700 square miles which are serviced by the Cleveland Electric Illuminating Company there are 138 industrial communities with a total population of about 1,925,000.

Electricity is generated at four interconnected power plants having a combined net capability of 2,021,000 kilowatts.[1] Generating capability was increased in 1958 by the addition of a 250,000-kilowatt turbogenerator at the Ashtabula plant and in 1959 by the same capacity supercritical steam generator at the Avon Plant. At the Lake Shore Plant a 250,000-kilowatt unit replaced in 1962 an old generating capacity of 130,000 kilowatts.

Electricity, an invisible "product," is sold to industrial and household users. The nearly 2 million population and the steadily growing industrialization of the area tend to guarantee an expanding market. Industry served by the Cleveland Electric Illuminating Company is well diversified, which is of considerable importance as far as the company is concerned. The fact is that profitability depends largely on the utmost utilization of facilities all the time. For this reason well-diversified industrial activity in the area means that all industries operating in the area will not be concurrently and simultaneously depressed. Hence, a certain minimum amount of plant capacity is always in use by one or the other of the following industries: iron and steel, automobile components, chemicals, machine tools, petroleum processing, or nonferrous metals. In addition, the various research centers—aircraft, rubber, chemicals, petroleum, and illuminating engineering—which tend to congregate in this area and the population growth and household units are important to the Cleveland Electric Illuminating Company.

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[1] Electric energy is sold at so much per watthour or, more generally, at a given amount per kilowatthour, which means 1000 watthours. This may represent 1 watt for 1000 hours or 1000 watts for 1 hour. 746 watts is equal to 1 horsepower or, inversely, 1 kilowatt (kw) is equal to about 1⅓ horsepower. The watt is the unit that expresses electric power just as horsepower (hp) represents power in mechanics; it is equal to the product of the volts (electric pressure) times amperes (rate of flow). Thus, 2 volts times 2 amperes = 4 watts direct-current circuit. (Source: National Bureau of Standards)

While the company's operations are profitable and no specific rate problem exists, the company is concerned primarily with two developments, namely: the steady rise of dollars spent per customer and the prospect of a declining rate of return in face of rising demand for electric power. In other words, the company's operating costs are tending to rise faster than the revenue from the sale of kilowatts of electric power. This, projected in the future, indicates that something must be done today to solve possible problems of tomorrow. Thus, the company is faced with the situation that, despite steadily increasing sales as expressed in kilowatthours, the rate of return on investment tends to shrink.

The company's production activity consists in converting coal into electric power. Coal is transported to the plant site in railroad cars or through pipelines (pulverized coal is combined with water and is transported just like oil). The coal is burned. The heat liberated by the burning of this fuel is transferred to boiler tubes filled with water. The vaporized water turns into steam pressure. This steam is then piped into the turbine where it is released, striking the turbine blades and rotating the turbine shaft. The generator, which is directly connected to the turbine shaft, also rotates; and the motion is converted into electric power by moving loops of wire through a magnetic field.

Each plant of the Cleveland Electric Illuminating Company contains facilities for coal storage, handling, and preparation equipment and huge buildings in which furnaces, boilers, and transformers and metering, control, and switchgear equipment are located.

The generating process is in the most part continuous. From the point of view of costs, it would be advisable to utilize the currently available capacity of approximately 2,000,000 kilowatts. Yet, the nature of demand is such that only a portion of this capacity is utilized. This is exaggerated when one of the industries serviced by the Cleveland Electric Illuminating Company operates at reduced capacity. A case in point is the last steel strike, which caused a shutdown for 116 or so days not only in the mills but also in related industries. Hence, during the 1959–1960 steel strike, a large portion of generating capacity was unused, causing an extraordinary rise in fixed costs per unit of output as far as the Cleveland Electric Illuminating Company was concerned. A similar situation developed in the spring of 1960 and in 1962 after the steel contracts were signed (without a strike in 1962) when steel demand slackened and steel mills were operating at a greatly reduced capacity. As a consequence of reduced electricity sales to steel, coupled with the cool summer, an unusually large portion of electricity generating capacity was idle. Back in 1959, fortunately, the hot and humid weather during the steel strike raised demand for electricity as a result of increased use of air conditioning throughout the sales territory. Thus, some of the losses were compensated by added demand in another sales sector.

Since capacity is relatively fixed while demand can widely fluctuate, it is a problem how the company can maintain a smaller capacity (smaller overhead) but satisfy consumer needs as required. The tendency is to demand electricity during a certain portion of the day to a greater extent than during certain other parts of the 24-hour day. If electricity could be generated in excess during those hours when electricity demand is low and this surplus could be stored, everything would be all right. But electricity cannot very well be stored. Therefore, if demand is below that of generating capacity, the plant stays idle and overhead costs are still incurred (probably not to the same extent as under operating conditions, but nevertheless to a substantial extent). Now, if for some reason or other demand goes beyond generating capacity, the Cleveland Electric Illuminating Company must, of necessity, refuse service, since it does not have anything to sell. Although the Cleveland Electric Illuminating Company can borrow electric power from other nearby companies, it can happen—as it did happen during the Second World War and the Korean War—that neither of the neighboring electricity works has excess capacity from which to lend enough to satisfy another company in distress. Of course, some critical users of electricity are protected by preference or by duplicate services from different distribution substations. Hospitals and telephone exchange substations are two examples. Furthermore, addresses of all iron lungs are available so that motor-driven generators can supply patients in hospitals. The latter, of course, require small amounts of electricity and can easily be taken care of. The problem is the volume user.

Because of the unique nature of electricity, its sale is different from that of tangible goods. It is true that every large-scale producer of a standard item must, in order to make the sale, have it ready and available at the time the customer calls for it. Nevertheless, instantaneous delivery is required almost exclusively in this industry. Since storage of electricity is not easily possible, the kilowatts of electricity must be produced at the same rate as required by consumer demand. Hence, the estimation of sales quantity must, of necessity, precede all production considerations. The Cleveland Electric Illuminating Company bases the production schedules on historical kilowatts sales of electricity as well as on customers' estimates of their electricity needs. Certain other indexes such as summer heat and humidity can automatically forecast added need, and production of power is automatically geared to this expected rise in electric power sales.

Once the forecast power sales are available, the coal is poured into the coal bin and will be burned at the rate required to generate a sufficient amount of electricity. Inside the furnace, the coal burns at a temperature of approximately 2888° Fahrenheit. This heat energy then, which is converted in boiler tubes into steam which passes to the turbines, rotates the turbine rotor. The rotation of the rotor, a huge electromagnet, generates electricity in the stator conductors. Finally, the electric power from the generators is increased from 13,200 volts to 132,000 volts so that large-volume transmission of the power can be made. This change in voltage requires the use of transformers and related equipment of large size.

To step up low voltage to high voltage may be likened to water pressure. Transformers provide pressure so that electric current flows (properly, is forced to flow) in the transmission and distribution lines to your home or plant. The customers themselves are supplied at voltages which are dependent upon the volume of power which they consume. Thus, from high voltage via additional substations, the voltage is stepped down continually. By the time it reaches the residential customers, who use from 1 to 20 kilowatts, it is at 240 and 120 volts.

Thus, in order to transmit and distribute power from the generating plants to the customers economically, the Cleveland Electric Illuminating Company has a high-voltage and a low-voltage distribution system. Lines connecting transmission substations to distribution substations are both underground and overhead. After its underground journey, the cable is brought up on a pole and is connected to the overhead distribution system.

The purpose of tracing the flow of coal to the main plant and its transformation into electric power on the one hand and the distribution of power on the other is to illustrate the close interrelationship between proper estimation of demand and the capability of meeting that demand. If at any given time excess demand (that is, demand greater than the plant kilowatts capacity) is not anticipated, borrowing from other systems, preparation of coal, and the whole burning process and other preliminary steps becomes impossible and the Cleveland Electric Illuminating Company must refuse service to customers. If customers are not satisfied, they move to competitors on a permanent basis. Hence, the loss is not temporary but permanent. The company's competitors are other power-generating systems: gas, oil, etc. If the service rendered is not satisfactory, the company loses customers who could otherwise help to utilize excess capacity.

Looking into the future, the management of the Cleveland Electric Illuminating Company foresees the problems of falling rate of return in spite of rising demand. This can partly be attributed to the excess capacity which the company must maintain to meet peak demand all the time. The question that arises, therefore, is how, by properly scheduling production, a better utilization of plant capacity can be achieved and a reduction of the cost of production can be effectuated.

Supply of electricity is assured so far as availability of coal is concerned. A certain amount of coal is stockpiled to ensure against any failure in service due to interruption of coal supply. At present, the company keeps an average of over 106 days' coal supply, totaling almost 954,000 tons, which represents an investment of close to 6.1 million dollars.

Questions. The student should be reminded that the Cleveland Electric Illuminating Company is not in any immediate trouble. The company is facing what might be a problem only if something is not done about the "gathering clouds." A serious trouble could possibly develop in the future. Yet, present conditions indicate that a better utilization of plant facilities would permit a better cost situation and a greater degree of profitability. Apparently, this company, as any other continuous producer, can enhance profitability by a better scheduling of production, that is, through a better utilization of capacity. This, in turn, can be achieved through a more detailed sales forecasting procedure. Also, the student should be reminded that a truly continuous producer, such as the Cleveland Electric Illuminating Company, has problems quite similar to those of the automatic producer. At times, the production problem depends on the adequate solution of the sales problem. Furthermore, that this is a public utility subject to government control should be kept always in mind.

1. As a result of fluctuating demand per day and even per hour of the day, a part of the generating capacity of the Cleveland Electric Illuminating Company stands idle during a large percentage of the time. Since electricity cannot be stored, the solution lies in raising demand for electricity during low periods of the day and season with that of supply (production capacity). How do you think the company could achieve a more continuous utilization of generating capacity?

2. A very large portion of production cost results from the overhead expenses. What methods that you can suggest would enable the Cleveland Electric Illuminating Company to cut the overhead cost?

3. How could you improve sales forecasting to improve the production scheduling and plant utilization problem?

4. Do you agree with the company's policy to build enough capacity to meet peak power demand all the time, or would you say that the company should keep a capacity equivalent to average demand and apportion the available capacity in a more economical manner? Substantiate your answer with an explanation.

5. In which way does the production control problem in the electric power industry differ from that of other continuous producers who sell tangible goods?

6. Comment on the amount of coal kept in storage (954,000 tons valued at approximately $6 million). Is it possible, in your opinion, to reduce the coal stored and yet assure continuity of operations?

13-3. CONSTRUCTION CEMENT COMPANY

The CCC was formed thirty years ago. Whereas it then had no plant, no markets, not even a single customer on its books, today the company is one of the important suppliers of cement, gypsum, and refractory materials in the United States. The first cement shipments, based on a subcontract deal, were made in the name of a large cement company which was unable to meet a commitment at the time. That was the beginning. Similar subcontract work was the bread and butter business of the first few years. While this was a rather insecure existence, it was considered satisfactory for a start. The owners at the time merely wanted to establish themselves in the cement business, and that was achieved by 1933, when the first real break came.

In May 18, 1933, the Congress of the United States signed the Tennessee Valley Authority Act. That was the first real break as far as the Construction Cement Company was concerned. The Act instructed the TVA to take over the construction of the Wilson Dam and an adjoining 60,000-kilowatt steam plant at Muscle Shoals, Alabama. The construction of the various projects under the TVA Act gave CCC a sufficiently large amount of business to establish itself in the cement industry on a permanent basis.

To solicit business, the CCC bid for a cement contract at the unusually low price of 97 cents per barrel. The company obtained the contract calling for 7,000,000 barrels of cement. Whereas other companies bid at $1.20 or more per barrel, the CCC gambled in the hope that the low-cost construction of a new two-kiln plant and its potentially low production costs would permit delivery at 97 cents. The plant was built (on borrowed capital) north of the Wilson Dam along the Tennessee River. Barge transportation was not only convenient but also costwise favorable. The total combined capacity of the first small plants was 500,000 barrels per year. The second plant had a capacity of 3,200,000 barrels per year. Thus, the total production capacity of the CCC was 3,700,000 barrels per year.

Owing to the depressed level of wages and low overhead costs on the new plant, the first big contract turned out to be very profitable. The depression hit the cement industry very hard. Nevertheless, the CCC prospered from 1934 to 1941. The Pearl Harbor attack made CCC one of the key firms in the United States counterattack. The company obtained large military contracts and at the same time it supplied a large portion of normal civilian demand also. With storage silos already built in Hawaii and with a fleet of ships, it was an important element in preparing for an offensive in the Pacific.

After the war the company built plants (see Fig. 1) both for cement and gypsum in strategic locations throughout the United States. Construction Cement Company has attempted recently to ship always from that particular plant or silo which was located closest to the customer or which could transport cement at the lowest total cost to any given destination. Occasionally, however, the closest plant was not the most desirable shipper in view of different rates on transports by various means. Rivers were usually cheaper than railroad or truck transportation. Thus the lower rates for waterway transportation frequently more than compensated for the distance differential.

With plant facilities and storage silos located throughout the country and having in 1961 a cement-making capacity of more than 8,000,000 barrels per year, the company could make substantial savings by shipping cement always from the best-location plant. The plants were located as follows: Plant A, on the East Coast, had a capacity of 1,700,000 barrels; B, in the Midwest, 2,000,000; C in South, 3,200,000; plant groups D, the original facilities 500,000; and E, 600,000. Gypsum products plants were located near the mining fields and had a total capacity of 55,000,000 square feet. Brick was produced near industrial cities, in particular near the large steel centers.

FIG. 1. An overall view of a modern cement plant. (Courtesy of Portland Cement Association)

The company's production control department, lodged in the home office building in Chicago's Loop section, will direct operations beginning with 1962 from a central nerve center. Orders are to be distributed among various plants and silos so that costs will be kept at a minimum.

Beginning with the recession of 1957–1958, and continuing during the relatively short-lived recovery of 1959, business has again declined. The decline was slow at first, but it nose-dived in 1960–1961. Consequently, a large part of CCC's production facilities stood idle and its storage silos were loaded with large quantities of unsold construction materials. The sudden and wide fluctuations in prices and the necessity to unload the accumulated cement, clay, and gypsum products resulted in severe losses in certain areas. While a long-drawnout strike in the company's Pennsylvania plant did not cause serious problems as far as CCC's ability to meet its delivery commitment was concerned, the fact that the plant remained closed during the 1959 shipping season necessitated long-haul shipments from faraway silos or plants. This raised CCC's costs in the Eastern market at the time price concessions became customary in face of the prevailing cut-throat competition and slackening construction activity.

Simultaneously with the generally declining economic situation, wage rates and prices of many purchased materials rose, however. While the outcome of the Pennsylvania plant strike was not unfavorable as far as CCC was concerned, it still forced 13% higher labor costs on the company than it had had in previous years. The increased labor cost had to be absorbed by the company, because in most sales districts, prices had to be kept highly competitive.

All this happened at a time when overall competition from both cement and other-than-cement makers made the making of business very difficult. Particularly severe was the competition in the Midwestern sector, where importation of foreign cement became a serious competitive factor. Near the Great Lakes regions, foreign cement sells for less than CCC can make the cement. It should be remembered that foreign competition, owing to the St. Lawrence Seaway, now open to ocean-going vessels, is no longer confined to coastal areas.

A severe blow, particularly in recent bad times, was the 1960 ruling of the tax courts severely limiting the depletion allowances on mining properties. A former decision was overruled and the company is being forced to repay back taxes from funds it had already booked as profit. The fact is that the legal depletion allowances are grossly inadequate. Thus, profitability is severely impeded by higher-than-just taxation.

The drastic decline of company profitability, resulting from a combination of all the above-mentioned happenings, made it necessary to exercise a much closer control over all expenditures than ever before. Unless the company succeeds in this endeavor, the rather severe declines in company earnings will make it difficult to acquire new capital to purchase mineral deposits and properties necessary for further operations or for upkeep and modernization of plant facilities. That these are the most important parts of company expenses goes without saying. To acquire either properties or facilities of the most modern kind, profitability must attract venture capital. Without profitability, the latter is not obtainable on the capital market.

In addition to all the above problems, the company must adapt itself to certain changing tendencies in cement delivery. Since truck delivery gained widespread acceptance in certain parts of the country, the modernization program should also take these developments into consideration.

The first attempt to control costs was the launching of a long-range cost-reduction program. The keystone in this effort is the central production control department which is to operate from the home office in Chicago, Illinois. The production-control department is charged with the responsibility of distributing plant facilities in such a manner that the best mileage can be gotten out of all plant facilities yet the total cost, including transportation, is kept at a minimum. From now on, all orders, regardless of origin, must be channeled through Chicago. Decision will be made there on the basis of 1) manufacturing cost, 2) destination of customer to the closest plant, the second or third closest plant, or storage silo, 3) plant capacity versus capacity utilization at the time the order is received, 4) the market price of cement in the locality in question, 5) the transportation costs from plant or silo by waterway, railway, or truck. Although all the above considerations are of equal importance, the main task of the production control group is to see to it that neither overutilization (overtime work and pay) nor underutilization takes place. Overutilization is permissible at a time another plant is idle only if the overall savings more than compensate for the fixed costs and contribute to profits to a greater extent than running the less efficient plant would.

The reason why the production control department is considered the mainstay of the company's cost reduction program can be explained by the fact that the largest portion of CCC's production expenses resulted from overhead associated with plant facilities. As long as physical facilities are well used the chances are that costs will remain relatively low. The problem, of course, is that demand for cement is both seasonal and cyclical. Thus, it is difficult to maintain a continuous flow even though the process could, theoretically anyway, be kept flowing from one stage of production to another. To balance production over the year, cement can be stored in huge silos in finished form or in the form of semifinished marble-sized clinkers. To conserve a part of operating costs, the pulverizing of the clinkers can be postponed until needed. (The huge rotary kilns burn the raw material into red-hot particles which, when cooled, form the clinkers.) However, when demand is high, a problem arises from lack of capacity in the grinding department which must pulverize not only current kiln output but also clinkers carried over from a preceding production period.

Cement quality is standardized in most plants of CCC; on the other hand, the raw material used to attain the predetermined cement quality (chemical attributes) is highly heterogeneous and varies with the deposits, which are of natural creation. Despite this, the chemical specifications of the raw materials —limestone, clay, shale, and blast-furnace slag—are quite rigid. Thus, for instance, the limestone must have little magnesium, flint, or quartz content, and here close quality control must be exercised. In the final analysis, cement is a predetermined chemical mixture of calcium, iron, aluminum, and silicon to be found in different compositions in mineral deposits and marine shells. CCC plants receive these minerals from quarries and, after the crushing operations, the materials are mixed to attain a proper blend. Both the crushing and the blending operations are done within the same plant where the burning or kiln operation and grinding (pulverizing) also take place. The low-cost plant in this respect is the Pennsylvania plant simply because it uses Lehigh Valley limestone, a naturally occurring "cement stone" consisting of nearly correct proportions of oxide, silica, calcium, and other ingredients.

The raw material is usually obtained through open pit mining and transported to the plant where the manufacturing process is as shown in Fig. 2. The process engineering department takes samples from raw materials for the purpose of determining the overall chemical content of the inbound material shipments. Once the chemical analysis of the raw materials is known, the percentage of the raw materials to be used can be found. The chemical analysis is necessary only when the limestone or other inbound material comes from a new seam or from a new quarry.

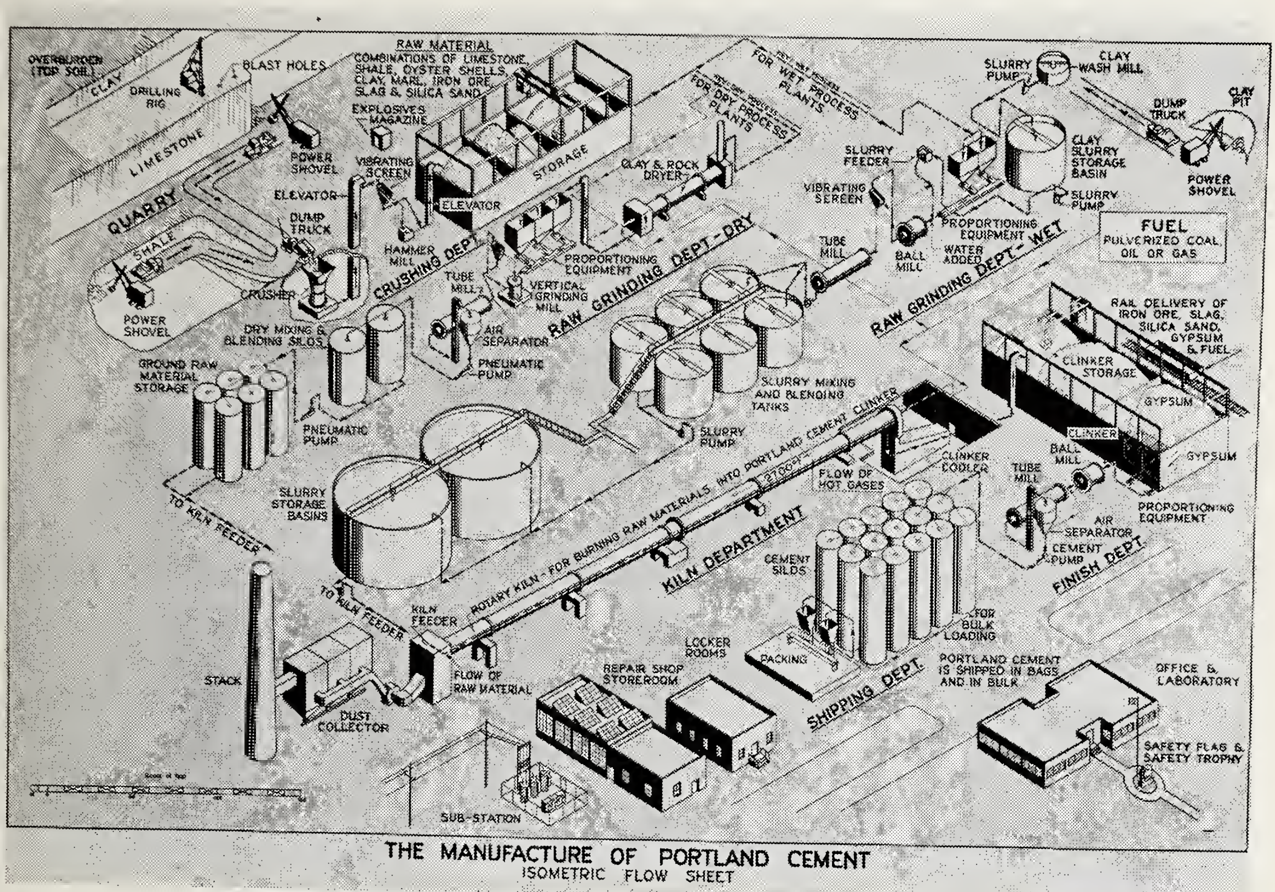

FIG. 2. Manufacturing process of cement. (Courtesy of Portland Cement Association)

The blending station merely follows the instructions which company process engineers (chemists) establish. The process sheet is usually pretty much the same, stating the requirement that 10% of *x*, 40% of *y*, 8% of *z*, and so on must go into 1 ton (5 barrels) of cement.

After the raw materials are blended into the right mixture, the preparatory work for burning the raw materials into cement is carried out by either the wet or the dry process. Depending on the raw materials used, one of the processes is more suitable. In the dry process, the mixture of ingredients is pulverized inside crushers and air suction draws out the pulverized material. In the wet process (since the raw materials are in some form of mud), the material is liquefied with water and mixed into the right proportion in a mixing tank.

The mixture, whether in dry or wet form, goes through the rotary kilns, Fig. 3, which are about 10 feet in diameter and 500 feet long, which fuse the materials into clinkers. In the wet process, this operation is preceded by a drying process.

The clinkers are finally pulverized and transported, by suction-operated pipes (vents), to storage stations. Since weighing, packaging and most of the other operations are done mechanically, the labor cost involved in the whole operation is negligible. Particularly for this reason, management of CCC concentrates on the utilization of facilities in the overall effort to cut down the costs of production.

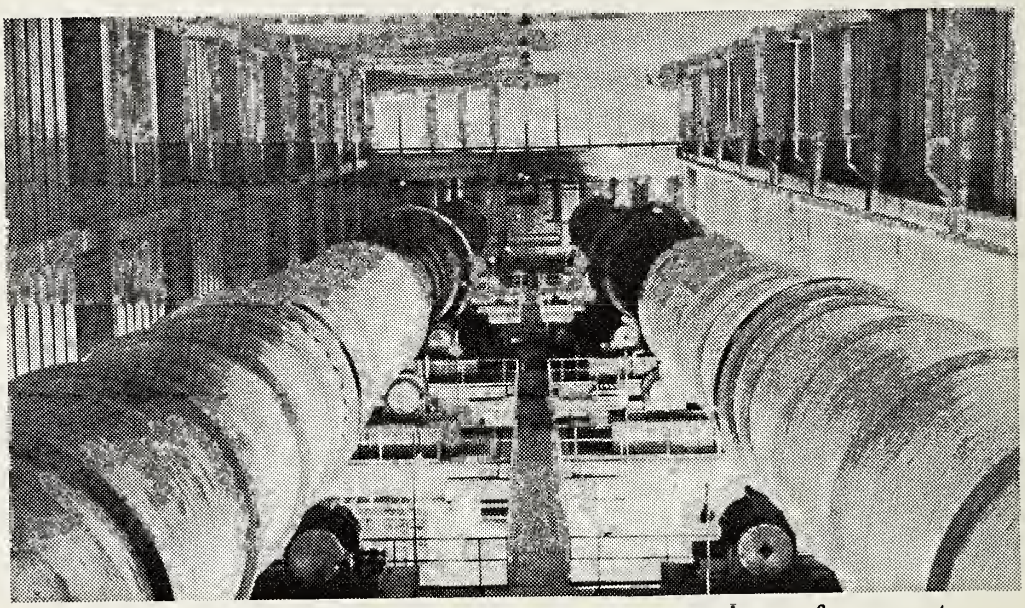

Fig. 3. Rotary kilns used in the processing of cement. (Courtesy of Portland Cement Association.)

Because the nature of cement making is dissimilar to a conveyorized assembly line, it must be apparent that a continuous production flow must be interpreted in terms of balance between processing facilities. Thus, the various equipments required must 1) in the dry process: crush → blend → kiln-burn → grind (pulverize) → weigh → package and 2) in the wet process: slurry → blend (mix) → kiln-dry → kiln-burn → grind → weigh → package, have approximately the same capacity, so that each successive operation will perfectly absorb the output of the preceding operation. Nevertheless, there is a continuous flow from station to station. Materials handling is done mechanically, and the labor cost is relatively minor. Operators are needed to control the heat in the kiln, switch the grinding mills on and off, start and stop the stone crushers, and start the mixer rotating. Generally speaking, however, the labor cost is a small fraction of total operating expenses.

Questions. 1. Comment on the company's method of production control.

2. Analyze the problem of the company by going through this procedure of analysis: a) What are the symptoms that indicate the company is in trouble? b) Ascertain the causes for the symptoms you list in part *a*.

3. Suggest remedies to the problems the company seems to experience in addition to, or in contrast with, the remedies the company has already undertaken.

4. To what extent do you agree with the company's method of attempting to exercise control over operating expenses and what criticism do you offer in respect to the company's flow control technique?

chapter 14

Continuous Production in Automatic Factories

THE SCOPE OF AUTOMATION

Because the economy is highly competitive, almost all companies face the question of when automation should be introduced to effect the savings which would make them competitive both on the domestic and on the foreign markets. Since the ever-increasing costs of many companies cannot be passed on to the consumer, it is necessary to absorb the costs, but it is also necessary to see to it that the costs are reduced where possible. In many instances the only feasible answer lies in automation.

Using automatic equipment means not only the replacement of men by using instruments to do what men did before, but an entirely new approach to industrial production. One no longer thinks in terms of individual machines or machine groups but instead thinks in terms of mechanically and electronically linked machine complexes and information-handling processes, that is, in terms of an integrated production system rather than a series of individual steps. If automation is to be introduced, products must be redesigned to make them producible through automatic processes, machines which can operate through electronic instruction processes must be designed, and raw materials which lend themselves to the process at hand must be selected. Another important problem to be considered is the market condition for the product or products in question. The system cannot be introduced unless the marketing system is able to absorb the tremendously increased output of automatic production lines.

When all the above factors have been seriously considered and found to indicate its feasibility, automation may bring the results desired. Results are usually attainable because the sequential steps in automated production processes are performed with great speed in unvarying cycles and, as a result, costs tend to be substantially reduced.

Before going further, let us investigate the term "automation." Basically automation is the *n*th degree of mechanization, but where mechanization ends and automation begins is difficult to say because there is no common agreement on the proper use of the term. While some degree of automation is prevalent in many companies, the push-button factory—where no work force at all is employed—is rare.

Barring lack of demand, automation is in most instances technically feasible; yet unless the cost of automatic equipment can be depreciated legitimately within a reasonable amount of time, automation might be a risky way of improving the company's competitive position.

The greatest savings offered by automation comes from the partial or complete elimination of certain cost elements. But it should be remembered that the capital costs to effect the savings might be greater than the saving themselves. Thus, eliminating the human element—that is, substituting power-driven machinery for human muscles, precision instruments for human sensory skill, and electrical circuitry for human response—merely shifts the cost structure from labor to capital. And unless the capital cost is considerably lower than the labor cost, it would be unwise to indulge in automatic practices. Of course, one factor that should not be neglected is that, once the investment is made, capital equipment does not make demands, whereas the labor force does make periodic wage demands. Hence, after successful automation, the company does not have to worry too much about work stoppages caused by labor unions, and this might be of considerable importance.

Since this book is concerned primarily with planning and, in particular, with production control, the question that arises is which functions, if any, production control groups must still perform after successful automation. The answer depends largely on the specific type of automation involved. In closed-loop (feedback) control, the production control work is done only at the outset when the computer is being programmed; thereafter, the computer takes over and runs the plant. Here the function of the production control department is to schedule the arrival of the necessary raw materials to assure a continuous supply at the same rate that production uses it. In numerical control, the process engineering (the programming work),[1] the scheduling functions, and the raw material procurement are retained except that the process engineering and routing requirements become somewhat different. The scheduler, however, might also be eliminated because the purchase orders might be automatically prepared by the computer itself as production records are compiled. The computer might be programmed in such a manner that when given raw material minimum levels are reached, the computer automatically prints out the required purchase requisitions, on the basis of predetermined lead times.

The programming work—which, of course, encompasses all production planning work—will require a somewhat different type of training than hitherto needed. In other words, production control work is still in existence, but it deals primarily with planning the "computer's job." The routine work, ordinarily performed by production control people, will subsequently be taken over by electronic devices.

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[1] In numerical control, programming work (that is, process engineering and routing combined) refers to office work which converts design drawings to reels of punched tape that will direct the cutting tools while the product is being processed. The programmers are the key men in the numerical control type of automation.

Furthermore, it should be remembered that a great deal of the work ordinarily done by production control departments is already done at the time the plant is built. Thus, production control to some extent is built right into the plant layout and plant operations do not require maneuvering orders through the shop. Once the raw material is available and is started down the line, it moves through the production process without human intervention except that at the end of the line the finished product must be hauled away.

SALES FORECASTING AND CAPACITY DETERMINATION

The capacity of the automatic plant is determined at the time the plant is constructed; that is, the daily, monthly, and yearly output capacity must be determined in advance. The usual basis is the long-run sales forecast, because an automatic plant is built for a relatively long period of time. It is of utmost importance to avoid "excess capacity" in the sense that the plant must periodically be shut down until demand catches up with supply.

It should be remembered that successful automation is no longer a matter of technology; it is now a matter of marketability. Unless the marketing system can find ways and means to sell the abundance of goods which automatic factories can turn out, the savings which would otherwise result from automatic fabrication is wasted on excessive storage costs, high interest charges on borrowed working capital, and last, but certainly not least, on undistributed fixed costs. Thus, the all-important prerequisite to the introduction of highly productive automatic manufacturing facilities is the presence, growth, and consistency of demand.

MARKETING PROBLEMS OF AUTOMATION

Working from the premise of marketability, the conclusion can be drawn that automation must be predicated upon the results of market research and sales forecasting. Regardless of the excellence of these activities, however, neither the proper assessment of demand nor the proper size of the plant will assure the consistency of plant utilization. Furthermore, even the production control department will be unable to properly regulate production and inventory levels unless the marketing organization works hand in hand with the production organization. Hence, in automation it is primarily the marketing system which must assure a relatively smooth flow of goods from plant to markets.

It is, then, up to the marketing organization to see to it that seasonal and cyclical fluctuations in demand are neutralized. Without going into details on this particular subject, it must be apparent that price and advertising policies as well as sales promotion are carefully correlated with production activities. In other words, it is no longer up to the production control department to regulate production single-handedly. The marketing organization and the production organization must join forces to even out the fluctuations in demand. Excessive demand fluctuations are evidently irreconcilable with effective automatic production. Although marketing and production are always related functions, in automation they are even more interdependent.

TRANSITION FROM MECHANIZATION TO AUTOMATION

The improvement over ordinary continuous production began in the 1930's when equipment manufacturers designed comparatively simple multi-station machines capable of carrying out several operations without a substantial amount of handling. Whereas hand transfer was still necessary, the movement of material from station to station was greatly facilitated. This was a prelude to automation, but still only continuous production.

Although replacing hand transfer by automatic transfer mechanisms was, in effect, automation, the use of the term "automation" would still have been inaccurate because employees were still needed as shown in Fig. 14-1. This type of automation has been practiced in most of our process industries for a good many years. What in the automobile industry is called automation is often not much more than the use of automatic transfer mechanisms.

Purists consider that automation is such only if and when all operations are regulated from start to finish through a myriad of electronic devices and the process is based on the closed-loop, or feedback, principle. No workers are needed except at the beginning of the line to feed the raw material to the first station and at the last station to haul the product away. To sum up, automation is the height of mechanization. It might start with simple automatic devices and end with nearly complete elimination of the human being from the scene. In the beginning stages, automation might only consist of a high degree of instrumentation. When, however, everything is regulated through electronic and mechanical regulatory devices, we have full-fledged automation. In automatic production, either the machine is so built that it always knows what to do to the product or a servo-mechanism (the mechanism which to the layman seems to think) controls the machine tools or the control settings to accomplish predetermined goals.

CONVERSION TO AUTOMATION

Time is vital in any plan to cope with automation. To compensate for its adverse effects on labor, management must think farther ahead than used to be the case. Also, the long-run effects are of far greater importance than the short-run effects. Yet, it would be false to assume that plants suddenly junk conventional facilities and replace them with automatic devices. It should

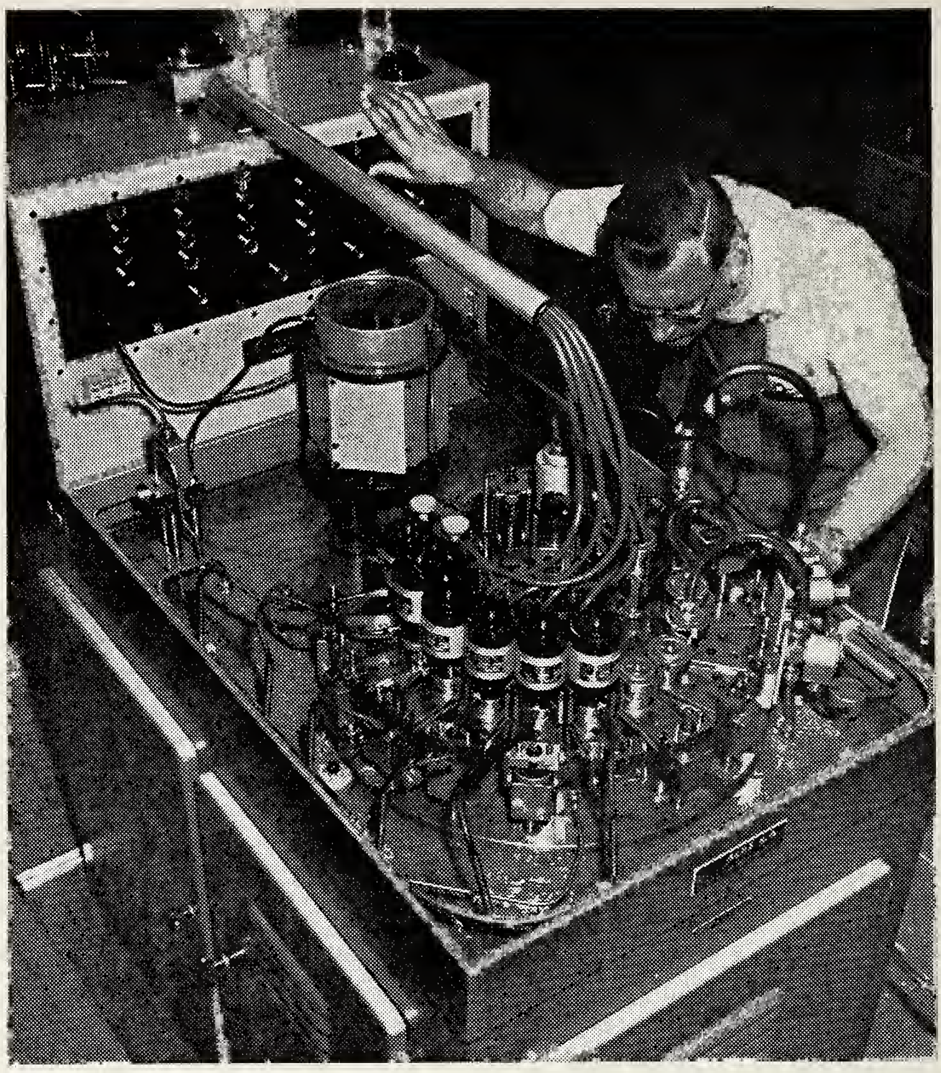

FIG. 14-1. Precision machines automatically perform 36 operations in assembling the ball and tip for ball-point pens. (Courtesy of W. A. Sheaffer Pen Co.)

be clearly understood that automation is a gradual process and largely takes place piecemeal. Conceivably this is not the right way to do things, but in most instances the "displacement of labor" problem carries a greater weight than one would ordinarily assume. Management rightfully hesitates to take drastic steps. Evidently the most formidable problem to cope with is the labor union, which tends to demand assurance that the displaced workers will be taken care of by retraining, transfer, or severance pay. At first glimpse of the featherbedding that is often associated with the installation of automatic devices, most responsible managements will think twice about whether the savings will cover all the costs. If the savings are not adequate to cover the cost which the replacement of labor brings about, the only feasible approach is to automate gradually and eliminate jobs in proportion to the natural shrinkage of the labor force and the operation of seniority rights.

ADAPTATION OF THE PRODUCT TO AUTOMATIC PRODUCTION

Relatively few products lend themselves to automation without redesign and a long-term freeze of that design. Hence, products ordinarly subjected to frequent design changes cannot possibly be manufactured with automatic processes. The reason is that the life of automatic equipment tends to exceed the stability of consumer tastes. If consumers crave for changes in a product year after year, that product is unsuitable for automatic mass production. Of course, if the volume of the product is large enough to keep equipment busy over a period of 24 hours most of the time year after year, a few years of design freeze may be adequate under the assumption that a relatively small plant can then be depreciated in one-third of the time, required by one-shift operation.

Without overstressing the point, there is a close relationship between design and process stability and the feasibility of automation and, conversely, between yearly sales volume and equipment life. If all these factors appear favorable, automation as a means of cost reduction is warranted.

Redesign of the product becomes necessary, among other reasons, because the product made through automatic processes will be handled not by people but by instruments and remote control tools. These instruments cannot think. They merely grab the item, provided its design permits automatic grabbing, feeding, or turning. Thus, the proper design facilitates automatic handling of the product in process on the one hand and enables automatic positioning in the various machines on the other hand.

PLANT LAYOUT AND STATION SYNCHRONIZATION

Chapter 8 dealt with the initial plant layout problems in continuous production. Some of the problems discussed there are applicable to automatic production also. In automation, the route is built into the plant layout in the same manner as in conventional continuous processes. The basic difference between automation and the conventional large-scale method is that, instead of handling and positioning the material manually, a mechanical electrical system is used.

The automatic production line consists of a large number of special-purpose machines. In the preliminary stages, the processing problems are solved in the same manner as in continuous production. Hence, after the sequence of operations is finalized, special-purpose machines will be designed or, if readily available, will be selected. The design of the special-purpose machine, however, is done with greater care than in the ordinary large-scale production, because an attempt is made to combine a large number of operations into one.

Which operations can be combined depends largely on the time element rather than on the nature of the operations themselves. Performance times must therefore be known. Two or three operations, provided each takes an equal amount of performance time, might lend themselves to simultaneous processing.

Ordinary milling machines, for instance, cannot mill more than two surfaces at the same time, but in automatic production it is worthwhile to design the position of cutting tools so that more than two surfaces can be milled simultaneously. The Plymouth Engine Plant,[2] described in a subsequent section, will indicate that milling can also be done on broaching machines. Boring and drilling provide an even greater chance for combining operations. In any event, a machine design engineer will ordinarily know how many operations can be combined and what obstacles to work simplification there are. It is obvious that the fewer the operations, the fewer the handling and positioning problems that must later be solved.

Each machine will perform a group of operations simultaneously. To make sure that there is a perfect production flow, machine performances must be balanced in terms of equal time requirements per operation, that is, per operation group. Unless sequential steps are perfectly synchronized, automatic processing is impossible. To enable synchronization, the part must undergo minor redesigns to accommodate this all important processing consideration. The practicality of design as far as adaptability to automation is concerned must always take precedence over consumer desires. Thus the product will always assume a shape which lends itself to automatic production, yet a shape which still retains its functional utility.

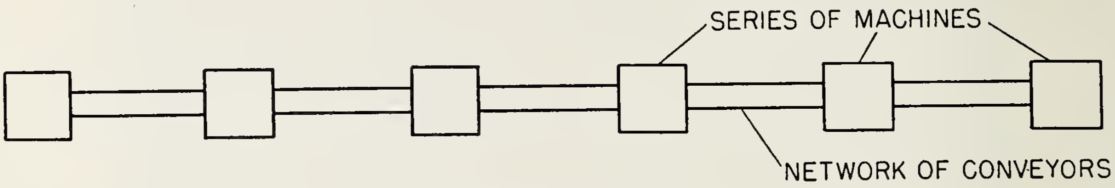

FIG. 14-2

Once the sequence of operations on a fixed path has been properly synchronized, a conveyor system to transport the workpieces from station to station must be designed as an integral part of the system. When all machines are finally interconnected, the automatic production line is ready. But, there is still something missing: the *automatic control system* which makes this complicated network of machines and conveyors function as an entity. What has so far been explained can be shown on the oversimplified diagram in Fig. 14-2.

AUTOMATIC CONTROL DEVICES

The heart of automation is the control system or instrumentation. The machines and the conveyors are important, yet without the control devices they cannot function. The control system is the factor which in fact replaces the human element in production. Whereas in ordinary continuous production, human beings start and stop the machines and position and handle the workpieces in automated production, instruments direct tools, conveyors, levers, valves, etc. as if human hands and decisions were involved. The control devices start and stop both machines and conveyors, make ejectors to operate, and change the position of tools etc. Thus, to the diagram in Fig. 14-2 we must add the control, or sensory devices shown in Fig. 14-3.

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[2] Recently renamed the Mound Road Engine plant.

Transfer or switching mechanisms work on various principles. Unless one understands some of the basic concepts in electricity, it is difficult to understand in precise terms how these control devices function. Let us, however, remember that the thermostat in our home heating system is such a device. It automatically starts and stops the furnace depending on the temperature in the rooms. Flashing neon lights are switched on and off automatically; doors are opened and closed in some chain grocery stores with magic carpets or electric eyes. The same principles can be applied in automation to start and stop machine tools, conveyors, or any other parts of the automatic system. Once the product starts down the production line, it goes through the whole line in a predetermined fashion from conveyor to machine and then from machine back to the conveyor.

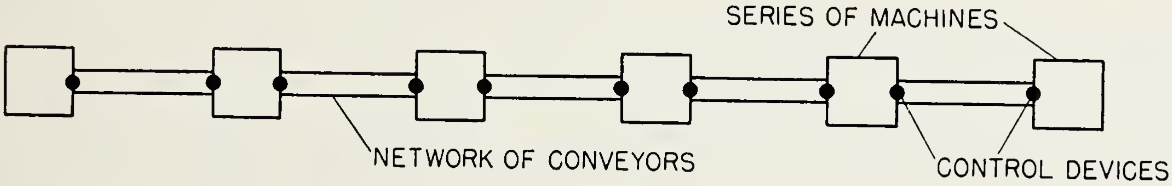

Fig. 14-3

The transportation of parts from machine to machine may also be accomplished by magnetic force. For instance, a magnetized belt might transport steel sheets in front of a series of punch presses. The belt would, of course, carry not only the punched sheet from one press to another but also the scrap created by the punching operations. Stopping the electric current collapses the magnetic field. If the sheets are held in the presses when the magnetic field is collapsed, the scrap will drop off.

In plants where human beings start, stop, and activate switches, judgment must often be exercised by the operator. The simple control instruments so far discussed cannot exercise judgment. They merely activate a lever, a conveyor, a moving part; they make no decisions. In other words, they do things mechanically. Thus, an electric eye lets a holdup man as well as a customer into the store. A shirt-folding machine folds whatever material passes by, be it a shirt or a sheet of paper, a tablecloth, or a rag. The control instrument cannot judge, measure dimensions, or check accuracy. If it is to do any of these things, a computer-like device (transducer) must be added. The latter, like an electronic brain, can make preprogrammed decisions and adjust cutting tools, regulate temperatures, decide on correct mixtures, and regulate and control many elements on a machine as required by the system. This kind of automation is referred to as closed-loop, or feedback control. In a schematic form, it would operate as diagramed in Fig. 14-4. This diagram would also be applicable in general when using simple transducers and tape control, except that the information flow would be one-way.

The mechanical and the electronic devices tend to overlap. At the one extreme are the automatic producers and handlers of material objects; at the other, the sophisticated analyzers and interpreters of complex data. In the in-between situation, computers may control complicated processes, such as oil refineries, steel mills, and electric generating systems, on the basis of interpretations that they make of data automatically fed to them about the environment.

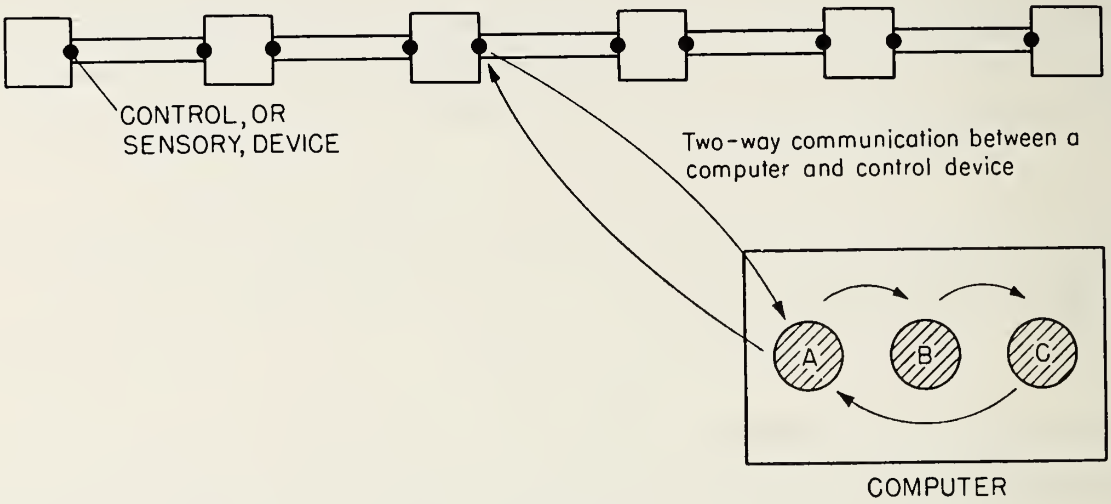

FIG. 14-4

Mechanical Devices. Automatic operations are inextricably involved with electronic switching mechanisms. For this reason it is difficult to segregate the mechanical from the electronic devices which make this network of special-purpose machines, special-purpose conveyor systems, and special toolings operate. Nevertheless, the above three components of automatic production lines are in themselves *mechanical devices.* What makes them move and behave according to directions is *electricity.* In other words, it is impossible to talk about these mechanical devices by themselves; with electrical systems combined they operate perfectly, but alone they are motionless.

With this premise in mind, let us speak about special tooling. The tools automatically adjust themselves in numerical control as well as in closed-loop (feedback) control. Thus, the tools must, of necessity, be connected with the electronically operating servomechanism.

Let us recall from earlier chapters that the machines must be tooled up before they can perform. In the machine industry tool-up refers to the affixing and positioning of special cutting, drilling, and grinding tools on the machines. Depending on the operation which the machine is being set up to perform, the appropriate tool must be mounted on the machine. If we want to tap a hole instead of drilling it, a tap must replace the drill bit. As the dentist must change his drill bit, depending on how close he is to the nerve, in automation the tool must be changed in an "automatic" manner. The tools will be changed automatically and the workpiece does not have to be taken out of the machine after each operation. Just how this is done must be explained.

Whereas automation is nearly impossible in job shops, in repetitive production—where operations do not change drastically—it is possible to run several different orders through the automatic production line and change, or rather adapt, the tools on the machines to different production requirements. This is particularly feasible when only the size of the product changes and the adjustment merely requires raising or lowering the tools. A case in point is the rolling mill. To meet differing customer requirements, only the rolls on the mill must be adjusted to the dimension the customer prescribes. The gage of sheet steel can be produced by putting greater or lower pressure on the slabs or ingots which pass through the various rolls. This can be done by raising or lowering the rolls.

Guided by punched tapes or electronic circuitry, machine tools, similarly to rolls in a steel mill, are automatically selected from a wide range of different tools to perform a variety of metal-working operations. This "flexible automation" brings mass-production benefits to repetitive producers also. Of course, "flexibility" must be given the right connotation. Obviously, there must be a great deal of similarity between jobs which can be done on these special-purpose machines provided with these specially designed, that is, adjustable tools.

The adaptable tool-up devices reduce the great financial risk which, in the recent past, owing to the lack of adequate demand and plant utilization, was imposed on the automatic production system. Before the adaptable automatic tool-up devices became a reality in repetitive-type operations, only those plants dared to automate which could count on relative stability of consumer tastes and use the same processes for years. Hence, automatic equipment would have paid for itself only if the volume over the life of the equipment was large enough to depreciate the cost of the equipment. Now, this requirement can be met much easier, since several smaller runs, when added up, might be sufficient to depreciate the equipment.

The same principle applies to self-correcting devices as applies to the use of adaptable tools. If a forging, for instance, is undersized and the machine is so set up that it cuts off one-thousandth of an inch of the forging surface, it will, in the absence of adaptable tools, automatically cut off that one-thousandth inch. The product will eventually be rejected because it will be undersized. To prevent parts from being qualitatively defective, the tools must automatically adjust as soon as the sensory device detects the size of the workpiece. By means of the sensory device and a computer, an appropriate adjustment of the cutting tool can be made. The quality of the workpieces at the end of the line is then bound to be always acceptable.

Electronic Devices. Electronic sensory devices and the mechanical devices are Siamese twins. The sensory device notices that the part is of incorrect size. This information is submitted to the computer. The latter determines the discrepancy and sends the answer back to the sensory device which, by means of the "muscle" instrument, automatically adjusts the tool. This is closed-loop, or feedback, control, because the sensory instrument and the control settings are connected directly to the computer without requiring human hands or human decisions.

If the computer is not directly connected with muscle instruments, either the information might be fed to the computer by an operator or the computer might be connected with the instruments it can read. In any event, if the adjustment is out of tolerance, a light might go on, indicating that an adjustment must be made. This is the so-called open-loop control. Here, the adjustment must be made by human beings, but the equipment otherwise works automatically. Correction is made only if the "danger signal" goes on.

The computer can calculate the error. Hence, self-correction requires a computer which must have been previously programmed for a specific purpose. However, the tools also adjust *without* a computer in numerically controlled systems. Here a tape indicates when the tool must assume a new position, but here errors caused by raw materials are, of course, not corrected.

Obviously these are not ordinary tools. They must be carefully designed and connected with a series of sensory devices and muscle instruments, and each movable part of the tool must have its own electric motor. As the tape, through binary-coded decimal systems, indicates cutting paths, sequences, tolerances, cutter shapes, and sizes, the tools are guided through the various workpieces as they pass by. Shells can be expanded, screws and bolts tightened, clamps made bigger or smaller, etc. A transducer converts the data into a form suitable to actuate the machine tool, depending on the size and dimension required. The cutting tools can be lifted up or down as required by engineering specifications. In other words, we are dealing here with special types of tools and gadgets which can be manipulated electronically.

NUMERICAL CONTROL

The greatest innovation which makes automation possible on a wider scale is *numerical control.* If we recall earlier explanations, we may realize that a majority of plants cannot be considered as pure continuous mass producers. Most plants fall somewhere between the continuous type and the repetitive and job shop type of production. From the explanation of automation so far the reader must have gained the impression that only companies which have certain types of products can even think about adopting automation. While the explanation is generally true, let us alter it a bit to allow automatic production when the plant makes a variety of sizes and shapes. We can go even further and state that, with the numerically controlled machine tools or adjustments, it is possible to produce quite a bit of variety.

Accordingly, a variety of products can be manufactured today with automatic equipment. It should be understood, however, that variety is interpreted in the sense we have explained in Chapters 8 and 12. The equipment is usually set up for certain kinds of variety. The tools and attachments on the machines are designed for a few dozen jobs, and as long as orders come in for any one of these product varieties the automatically controlled machine tools or control settings can be adjusted to attain the dimensions or product variations desired by the customer. In other words, we are speaking of a repetitive type of production rather than the pure job shop.

A numerically controlled drill press, for instance, can drill only as many different sizes of hole as there are drill sizes positioned on the machine. Obviously, if a size that has not been thought of in advance is wanted, the tape-controlled tool cannot possibly drill the size of hole desired, because the machine lacks such a drill bit. In other words, the machines must be able to drill certain holes to begin with. The numerical control will, however, instruct the drill press as to which drill must be used, how deep it must go down into the metal, and at which section of the surface the hole must be drilled.

Operation of Numerical Control

From what has been said it should be apparent that we are dealing with highly specialized machinery which is built specially for a limited number of tasks. The machine can perform these jobs, but nothing else. The task must be selected and the machine will perform it without human intervention. That is, the machine must be told through tape, punch card, or some other electronic means which one of the jobs for which it was built it must perform.

Numerical Codes. Tools, valves, or parts of the machine that must be adjusted to do different jobs can be adjusted electronically through tapes. These tapes are somewhat like those the player piano uses. Depending on the numerical code, certain keys on the keyboard of a piano will be hit. In a similar way, each switch which moves a segment of the machine has a code number and, when this code number is punched into the tape and the machine reads the instruction, the tool or valve will automatically move to the position in which it must be to perform the task at hand. These numerical codes must, of course, be developed first. Once a code system is established, the next thing to do is to prepare the tape. The coded tape will ultimately make the adjustments on a machine in the same manner an operator would make them. Code and tape program the machine.

Blueprint and the Code System. The blueprint gives the dimensions, pressure, temperature, or other variable.[3] This information must subsequently be placed on the tape in coded form. In a machine tool adjustment, the depth of the cut, the speed and feed of the cutting tool, and the angle of the cutting tool must usually be set by the operator when he changes from one setup to another. What an operator really does is turn a knob on his machine just as we turn the dial of a radio or a television set to select a station. In numerical control the same thing is true. By turning the dial (knob) a few calibrations, we actually move a cutting tool a certain distance in a certain direction. With another dial, we move another adjustment in another direction.

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[3] The programmer decides at this point how the job in question is to be done. Simultaneously, he prepares instructions on the blueprint itself (in coded form) for each move the tool or workpiece must make—a separate instruction for each move of 0.001 inch in the case of contour cutting. Accordingly, any part that can be mathematically defined and is suitable to the kind of work the machine is able to handle can be machined by means of numerical codes.

The design drawing will indicate the dimensions, for instance, on a workpiece. The machine tool must cut off a certain amount of the metal, and to do so, the cutting tool must be so positioned that it cuts a predetermined depth into the surface of the metal. Depending how far we move the cutting tool it will cut more or less into the metal. The operator turns the knob and, in turn, the knob positions the cutting tool. There is a direct relationship between the turn of the knob and the position of the cutting tool; each calibration on the knob represents a given tool position. Now what we have to do is to impose the code system on the blueprint. Thus, to set the numerically controlled machine, three basic things must be done: 1) a code system must be developed, 2) a tape must be prepared, and 3) the blueprint must be interpreted into tool positions. In other words, steps 2 and 3 are interrelated in a sense that in numerical control the blueprint must be interpreted in terms of tool positions. Thus, the tape is a perfect replica of the blueprint, except in different form. When the tape is placed in the automatic equipment, it will guide the workpiece through the production line, and at each work station it will direct the cutting tools, the position of the table, the speed of the cutting tool, etc. as required by the design drawing. An operator might turn the knob a bit farther than necessary and ruin a workpiece. The tape will never do such a thing, unless the typist who prepared the tape made a mistake, and that is unlikely because the tape double checks itself. To explain how is beyond our purpose here.

AUTOMATIC TOOL POSITIONING

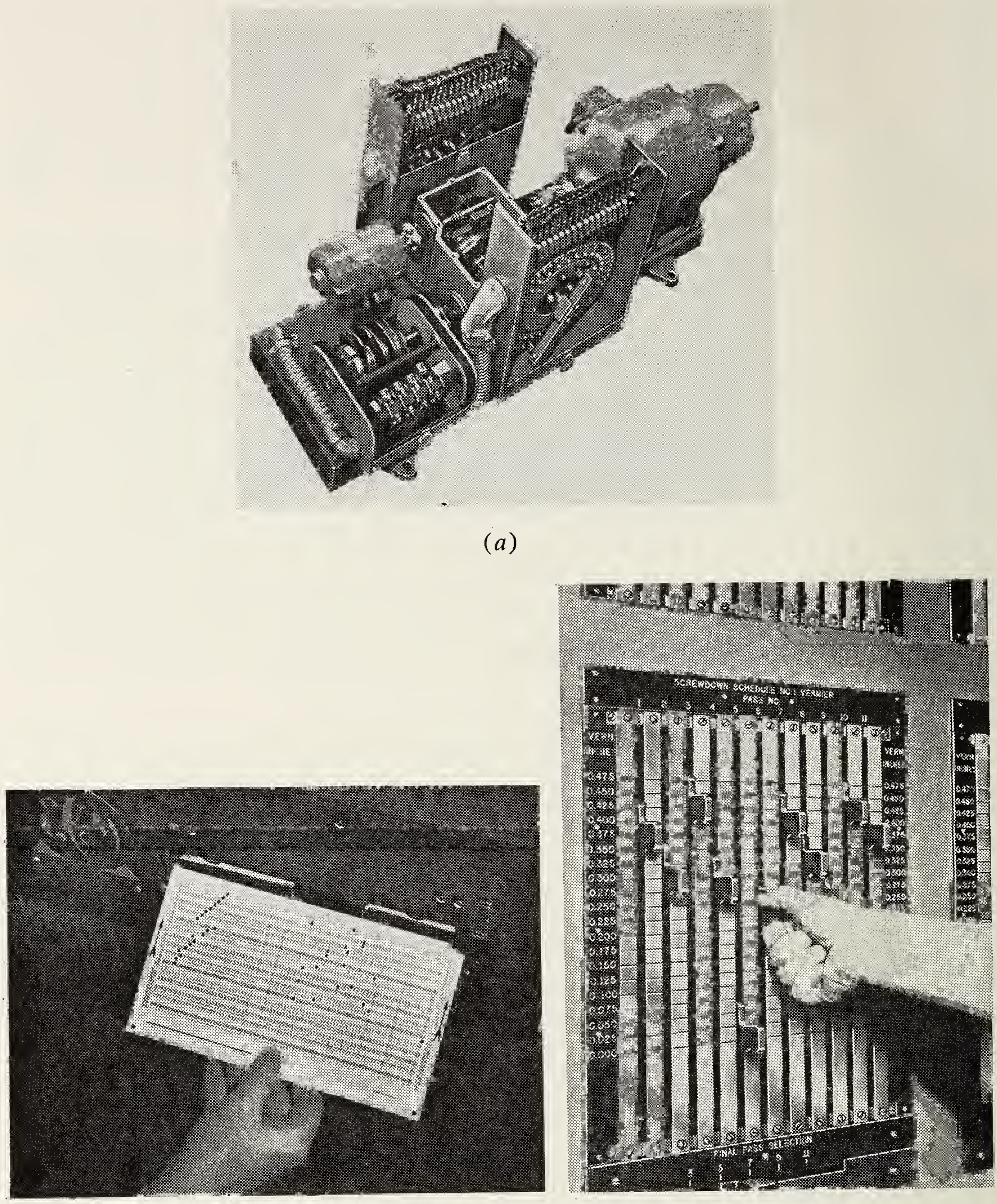
Actually, not only the tool, but the workbench and any other part of the machine which requires adjustment to do different tasks must be directed through the tape. The tape, then, positions each movable part individually. This means that each adjustable part will be driven by its own electric motor. (There are a lot of motors on automated machines!) In turn, each motor must be instructed individually by the tape. The motor is connected with a lead screw. The motor will turn the lead screw to move the workpiece at commanded speeds and feeds; will measure out the cutting depth, place the tool in the appropriate cutting position, and do as many different things as are needed to set up the machine. The motors moving the lead screw are responsible for making the various preplanned adjustments, starts, and stops as commanded by the punched tape. Each time a given perforation passes between given mating wires, electric currents or impulses are transmitted over the wires to the motors which, through transducers, make the necessary adjustments. Because the lead screw acts in the same way as a TV dial and in a sense brings about a given tool position, it must be of a given size and each quarter, half, or full turn must represent an upward, downward, left, or right move of a tool, table, or valve.

Rolling mills used in the fabrication of steel are a good example of how moving parts can be automatically positioned. The device shown in Fig. 14-5 (*a*) is called a roll-position sensing unit. This sensing unit can be actuated by a punched card, which is placed in a card reader as shown in view (*b*), or by a slider-contact panel, view (*c*). Either the punched card or slider-contact panel is set up to send signals to the sensing unit for a complete rolling schedule. The rolling mill operator will push a button to start the steel through each pass between the rolls of the mill. Signals sent to the sensing unit will provide accurate directions for stopping the rolls on each pass and will also direct positioning of the rolls for the next pass. The roll-position sensing unit reacts to the signals and through a synchro-tie motor on the unit actuates a companion synchro-motor for the drive which positions the rolling mill rolls.

AUTOMATIC MEASUREMENTS

Because numerical control also revolves around measurements, let us discuss how these measurements are made and how measurements and automatic operations are related. In speaking about measurements, we note first that the computer (to be explained subsequently) makes measurements in pretty much the same way that the tape-controlled machine tool or other tape-controlled automatic equipment makes them. When we focus the lens of a projector, we turn it clockwise or counter-clockwise. But what we really do is move the lens forward or backward and therefore closer to or farther away from the film. When a lead screw is making an adjustment, it is turning a certain fractional amount. In the case of a cutting tool, the command might be to move 2 inches to the left and 1 inch, upward counting from zero position. (Every command refers to zero position because measurement is made from a point of departure.) When the lead screw is turned, the turn or fractional turn corresponds to a given distance in some direction. A 1-inch lead screw divided into 10 threads will shift the position of the bench, tool, or whatever it is supposed to position by ½ inch if it is given one half turn. By the same token, two decimal turns would correspond to $\frac{1}{20}$ inch.

Measurement and positioning also require a transducer which must be hooked up with the lead screw. The transducer converts electric currents or impulses into mechanical action in somewhat the same manner that a thermostat converts heat into mechanical action. Thus, the rotation of the lead screw depends on the tape-given and coded electronic signals or voltage.



(*a*)

(*b*) (*c*)

FIG. 14-5. (*a*) A roll-position sensing unit, (*b*) a punched card in card reader, and (*c*) a slider-contact panel. (Courtesy of The Electric Controller and Manufacturing Co.)

Just as computers operate under the digital or analog system, so transducers operate according to the variability of electrical power (analog) or according to electrical frequency (digital). Analog transducers reflect a variable electric power precisely proportional to the rotation of the input shaft. Digital signals, however, appear—somewhat like Morse Code—as individual electric pulses; that is, the output does not vary in electric voltage (intensity), but merely varies in frequency. Without going deeper into the electronics of information transmittal through servomechanisms, let us merely say that the code can express the number of turns the lead screw must make in order to be precisely at the point where it should be. How does the typist who types the tape know how to convert the blueprint-given technical information into binary-coded decimal form? He merely types regular numbers—code numbers—and the specially designed electric typewriter-like machine, Fig. 14-6 (*b*), converts the regular numbers into binary coded decimal forms as a matter of course and punches a series of holes in appropriate positions on the tape. Obviously, prior to the coding, the process engineer had to establish a code system right on the blueprint. Incidentally, in this kind of automation, this is the process engineering and the routing function.

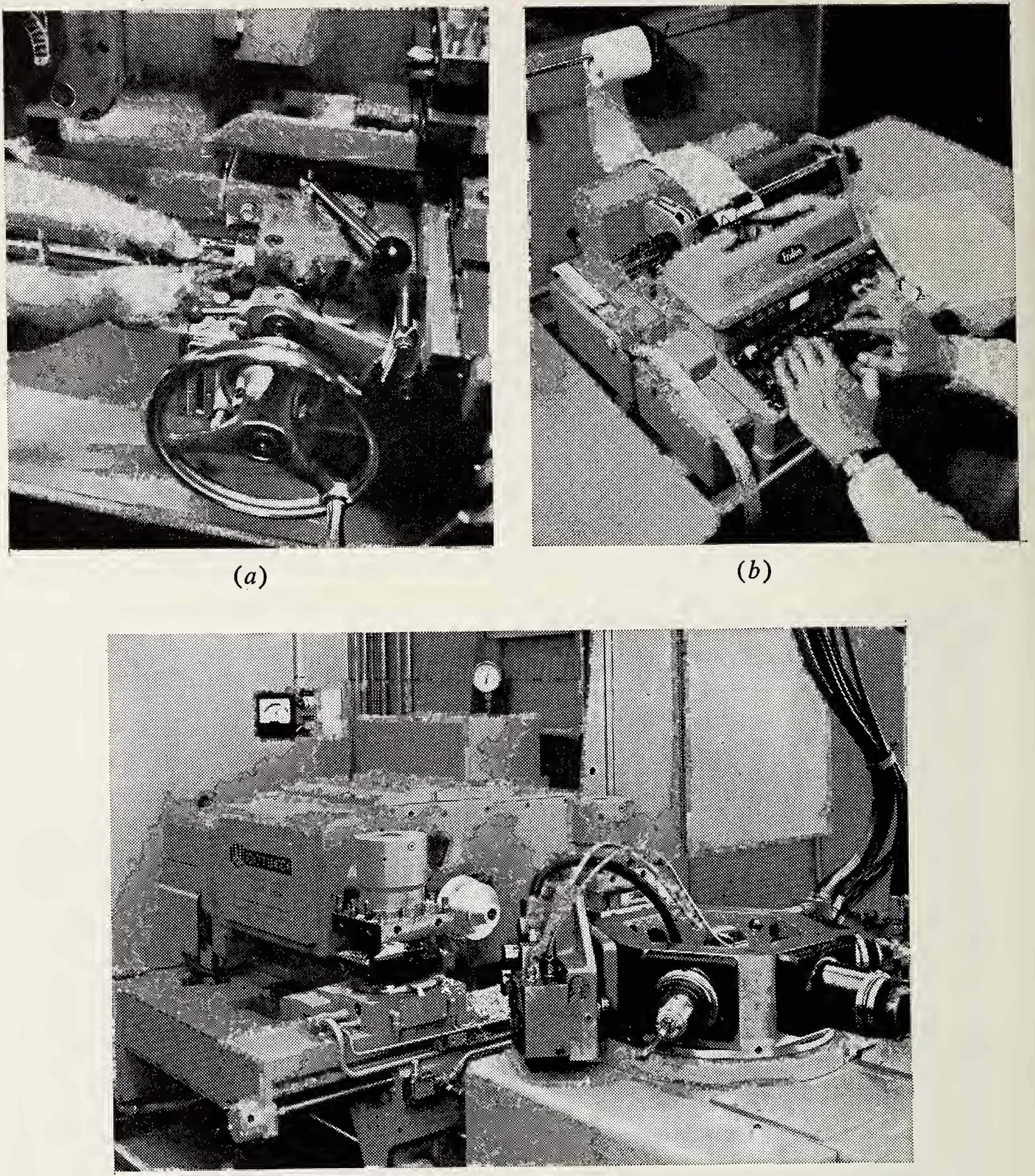
The design specifications, as taken off the blueprint, are assigned certain numerical codes indicating how far the lead screw must move to achieve the desired tool positions. As the tape guides the tools, the conveyor moves the item through the production line. In other words, the table stops at the correct locations, the tools adjust as if invisible hands moved them, the coolant automatically turns on, and the operations are performed fully automatically.

ROLE OF THE COMPUTER IN AUTOMATION

Automation is controlled by servomechanisms. The transducer is one of the many kinds of servomechanisms. The servomechanism varies in complexity from that of a thermostat to that of an electronic computer. In some process industries, the computers might control the operation of whole plants single-handedly, that is, after being programmed to do certain things in the same manner as, in the numerically controlled system, the tape is prepared.

Specifically, the computer is a reproduction of the human brain's method of functioning in electronic form. It consists basically of three parts: 1) the input-output unit, 2) the memory unit, and 3) the calculator unit. In other words, it is not one machine, but a combination of three interrelated electronic units. As far as automation and automatic controls are concerned, the memory unit seems to be the most important part, but of course this is only a theoretical emphasis, since all three parts must be present to function purposefully. The memory unit stores information either on tapes, magnetic drums, or punched tapes or cards. When called upon, the memory unit will recall whatever information is needed in order to control the automatic production process. Through this memory unit, information can be compared with added new information (input) to make an appropriate decision (feedback concept).

It should be remarked, however, that the complex computer is only a part of the automatic production process. Automation does not necessarily require a million-dollar computer, or even a less costly one. As long as simple transducers can interpret electric currents or frequencies into action by moving a



(*a*) (*b*)

(*c*)

FIG. 14-6. Advantage of automation. (*a*) The hands shown will require 2½ hours of tool setting. (*b*) The hands shown will do the same tool setting in 6½ minutes by the numerical tape control process. (*c*) This turret lathe can be controlled by the tape being prepared in view (*b*) to perform the same operations as the lathe in view (*a*). (Courtesy of Jones and Lamson Machine Co.)

lead screw, automation can go on without computers. However, when *decisions* must be made on the basis of raw data to control the production process, a computer is needed.

To illustrate the strictly mechanically operating production line, let us take the example of the automatically operated paint brush. It dips a brush into paint, lifts the brush, and finally makes a horizontal movement on the surface of an object which passes by in front of it. One day the president of the company wants to see what makes it tick; he looks into the machine; and the machine dutifully paints a stripe on his bald head. Now, hypothetically speaking, if this was a digital-computer-controlled automatic line, the accident could not have happened, because the sensory device would have instantaneously noticed that the object to be painted was different.

At any rate, the sensory device is designed to measure the object and transmit the information to the computer's input-output unit, designated by *A* in Fig. 14-7. Assuming that a workpiece is 11 inches—and not what it is supposed to be, the memory unit *B* hooked up with *A* would be called upon. If the memory unit *B* indicated that the dimension should have been 10 inches, the calculating section *C* would compute the difference, which is, of course, +1 inch. This information would—always in electronically coded language—be relayed again to the memory unit. The latter has presumably been programmed by an expert indicating what must be done in case the object is +1 inch out of tolerance. When this preprogrammed instruction is found and relayed as an answer to the output unit *A*, it will reach the sensory device to make the necessary adjustment. This whole complicated procedure has, of course, taken only split seconds, and an almost instantaneous adjustment is being made at the machine. The information flow and the calculations are fantastically fast.

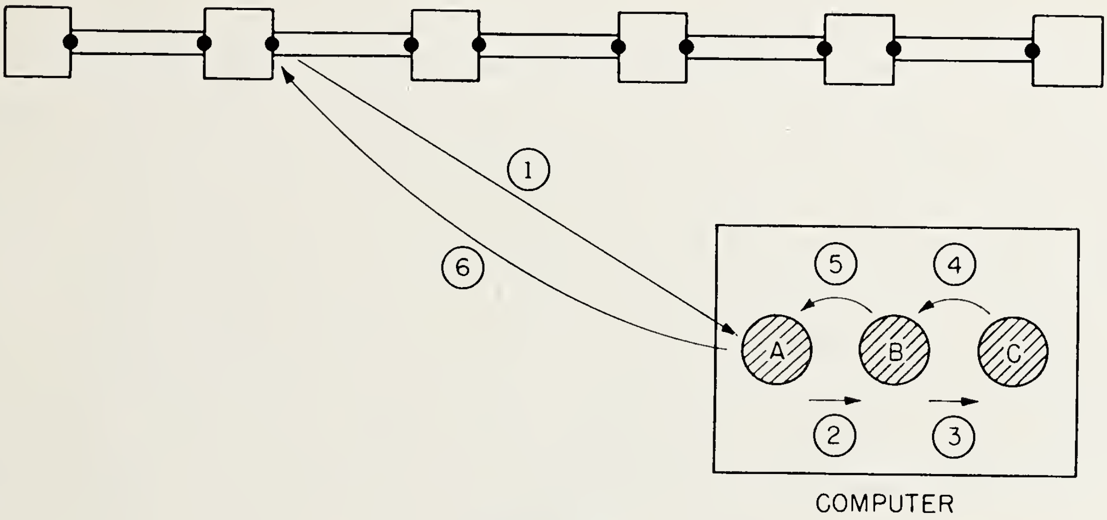


FIG. 14-7

While step 6, Fig. 14-7, gave instruction to the machine, it should be understood that a programmer must have expected to begin with that some workpieces would be out of tolerance. Once the computer found out that the discrepancy was +1 inch, it simply picked out of its "memory" the instruction which was applicable to the solution of that specific problem. Computers are "illiterate," and they must be told what to do and how to do it by man. This is known as programming the computer. In case a remote possibility was overlooked and the machine on the automatic line encounters this unprogrammed problem, the same procedure will take place as described above, but no action can possibly be relayed to the muscle instruments. Obviously then, the input unit must receive "raw information" from sensory instruments (indicated in Fig. 14-7 by dots) which, based on computations and comparisons with other data the memory unit contains, will be digested; and the solution to the problem will be given to the machine. Here, there is a two-way communication between machine and computer whereby the latter does the feedback control; whereas in numerically controlled operations there is only a one-way communication from tape to machine via the sensory device.

Again, it should be pointed out that no computer is necessary in numerically controlled automatic systems. Yet, computers might be very useful. The computer is able to reduce the tape preparation time to a fraction of the time otherwise required. The tools are controlled by the coded tape—via the transducer—and not by the computer.

Computers used in automation can be either the analog or the digital type. Smaller computers—the analog type—might be hooked up with the production process to control only certain critical portions of the process rather than the whole process. Analog computers are so programmed as to represent a model analogous to the process through which the product must move, and they transmit coded information in variable electrical power which is precisely proportional to the rotation of the shaft. In contrast to this, the digital computers are high-speed calculating machines which receive and return information based on preprogrammed calculations in frequency-coded form. These precipitate an electrical output appearing as individual electrical pulses. There are incremental and absolute digital-type computers. In the former, the total electrical output is simply a chronological series of incoming pulses which, when tallied, give precise instructions on how many turns the input shaft must make. The absolute digital computer, however, gives unique signals—similar to SOS or radio code signals—as additional rotations of the shaft take place. Therefore, for each additional turn, or fractional turn, there is a different signal. Evidently, depending on the computer used, the whole electrical system must be built around a selected principle. In digital computer communication, the sensory device and the computer close the loop and hence provide closed-loop or feedback control.

It is apparent from the above that the sensory device and computer are intimately related. The most important of the two is probably the sensory device. Computers will only digest, evaluate, and return an answer—an electronic voltage or signal—to the sensory device; whereas the latter sets into motion motors which, in the final analysis, make the needed adjustments in accordance with tape-given or computer-given command.

In the final analysis, computers do two things:

1. Perform work otherwise done by industrial engineering and production

control groups. Here the purpose is to accelerate the performance of these activities. Specifically, the computers:

   a. Standardize design elements and criteria for parts to be produced by numerically controlled automatic systems.
   b. Define mathematically the part to be produced.
   c. Facilitate the tape preparation in numerically controlled automatic systems by remembering the code equivalents for given tool positions as read off the blueprint.
   d. Aid in production control work, particularly in efficiency calculations. To this latter aspect a separate section will be devoted.

2. Find the best setting for the various control instruments in process industries such as oil refineries, chemical plants, steel mills, and power-generating plants.
   a. Digest raw data obtained from instrument readings furnished to the computer either by an operator or directly by instruments, in which case the computer itself both obtains and digests the data. This is not automatic control yet, however. Here the computer merely replaces human judgment and "feel" with precise calculations. The control instruments attached to the equipment are still operated by men who monitor the production process. The instrument merely suggests how the controls should be set based on heat, temperature, pressure, and density relationships.
   b. When both the instruments and the control settings of the controls are connected directly to the computer, we have *closed-loop computer control*; hence, no human intervention is necessary to run plant facilities. This is automation at its best.

The larger the computer, the greater its capacity to memorize information, digest raw data, and give a coded answer that is transmitted numerically. The fact that the memory unit of the computer is capable of containing a great amount of information makes computers extremely useful in production control. The programmer can determine, for instance, every possibility which can conceivably go wrong. If the item is undersized, say, by 1/10,000 inch, the programmer might indicate in a coded form—pulled out of the computer memory unit—that in this situation the cutting tool must be lifted appropriately to prevent taking a deeper cut of a metal surface than is required. The same thing must be done for a whole series of size differences. Thus, the control program must be so inclusive that it contains not only routine solutions to routine problems but also solutions to the most unlikely yet possible condition. Of course, the digital computer is more suitable for this kind of work because it can, to some extent, figure out certain answers on the basis of raw data. The analog computer cannot calculate anything. The programmer must state precisely in the program that, in situation A, alternative 1 must be used; in situation B, alternative 2 must be used; and so on. In other words, the problem and its solution must, in analog computers, clearly be programmed. The analog computer, as it operates, is somewhat like a pinball machine in which each bounce of the ball has been predetermined. Whichever bounce takes place, it is registered on the front of the machine. Each bounce possibility has a separate circuit and indicates the winnings.

AUTOMATION AND OPERATIONS RESEARCH

Although no specific mention has so far been made of operations research as it is related to automation, we have actually been speaking about operations research; we just did not give a name to it. When we discussed the computer and its role in process control, we said that the computer makes certain computations on the basis of raw data. These mathematical computations which ultimately set the instruments in closed-loop control are nothing else but operations research.

Operations research is a mathematical method of solving production problems. In the process industries, the production problems are quite different than in the metalworking industries. In the chemical industry, for instance, the production process is invisible to the naked eye—the chemical reaction takes place inside a vat or tank. The only way we know what has already happened is that we know the time required for a certain chemical reaction to be completed and that given pressures and temperatures will produce given results. Just as we know that cooking something in a pressure cooker will shorten the time required to complete a dinner, so in the chemical, oil refinery, and cement industries we know how the pressure is related to the temperature and to the characteristics of the material used. We know, for instance, that potatoes cook faster in a pressure cooker than meat does and we know, through experience or experiment, the ratio between these factors. In the process industries the operator's task is to check the various instruments which indicate pressure, temperature, humidity, pressure versus temperature, and humidity versus pressure. Depending on the pressure, the temperature can be lowered or raised without loss of efficiency. The operator can regulate the pressure by turning certain valves. Normally when we rely on the judgment of the operator, it is this skill for which we pay him wages. In the machine shop the employee knows how to operate a milling machine; whereas in the chemical plant or oil refinery we pay the employee high rates for his skill in reading instruments and for his knowing how to regulate the instruments to accomplish desired ends. An employee is considered "good" if he has the know-how about precise relationships between pressures, humidity, and temperature. As the operator reads off the conditions inside the tank or vat from instruments, this information can be fed to the computer. After computing the proper combination between the settings of dozens and dozens of thermostats, pressure gages, humidity control instruments, etc., the computer gives the answer to the operator. The operator can therefore read from the computer what adjustment must be made. This is not automation as yet, but here the decision which the operator ordinarily has to make is transferred to a computer which, based on the knowledge of mathematical relationships between variable factors, has computed the proper setting. Now the operator simply adjusts the valve or makes whatever adjustment is necessary. The computations were necessary to achieve proper control over plant operations. The method of achieving the best answer was through operations research, that is, through mathematics.

In closed-loop control, which means that plant operations are controlled by instruments and no human intervention is necessary, the computer is hooked up directly with the various instruments. Hence, the computer automatically collects information to be digested and evaluates it according to a given model (the mathematical equivalent of the various relationships between pressures, temperatures, and densities). Since the computer has a two-way communication with sensory as well as muscle instruments, it automatically resets the control instruments as changes in pressure and temperature take place inside the tanks. The computer thereby actually controls the chemical operations in the same manner as a housewife operates the controls on her oven. By testing the meat with a fork and by looking at the discoloration, the housewife works with several factors: feel, color, knowledge of the total time requirement, and the temperature to learn how to adjust the control, that is, raise or lower the temperature in the oven. When the results of computations made by the computer are automatically transmitted to transducers which turn a knob or change the valve setting and thereby effect a known change in the process flow or chemical reaction, we have closed-loop, or feedback, control.

Because the control of the operation inside the tank depends on conditions which only instrument readings can reveal—evidently the only way we know what happens inside a blast furnace is that we check with an instrument—the resetting must be based on careful correlation of interacting factors. This, when done mathematically, is operations research.

Although efficiency in processes is achieved through the computations, the operations research calculations here served automation. Because the computer can make better and faster readings as well as make better judgments, since it makes them mathematically, than operators can, we actually achieve better process efficiency. But this is only a by-product of automation. Here the purpose is to replace the operator with instruments and thereby make industrial operations independent of human frailties, human errors, and human variable influence on results. The computer, assuming the mathematical formula is correct, does not make mistakes. The computer is needed here because the variables which must be compared can no longer be regulated by the simpler thermostatic controls. The latter can merely convert variations in temperature or pressure—which cause movement in a small metal spring—

into electrical signals to switch the temperature controls on or off. In the process industries, questions of the precise mathematical relationship between a control setting and a series of instrument readings must be determined and calculated. And the calculations must be made constantly to keep the process under control at all times.

The next chapter will also deal with operations research. However, in the connotation used there, operations research has nothing to do with automation and process control. The student should therefore distinguish between process control and efficiency calculations, although in both cases operations research techniques may be employed.

COMPLETE AUTOMATION WITH COMPUTER CONTROL

At the time of this writing, computer control is firmly established in many industries, including the chemical, power generation, oil refining, and cracking industries, rolling mill operations, and cement making. Here, however, only a few examples which can be reasonably well understood by the student will be cited. Most chemical processes are invisible because the chemical transformation takes place inside a tank. Only the knowledge of what the control gages indicate in terms of quality would permit serious discussion of the production process as a whole and reveal something about the nature of automatic control. But by reducing the problem to reading control instruments and correlating the readings with one another, the nature of automatic control becomes reasonably clear to most students. The same approach would apply to generation of electricity. Here the coal is automatically pulverized and burned, the heat is transferred to steam, the steam rotates the turbine by hitting fan-like blades, and the steam turbine rotates the generator which convert steam power into electric power. How the automatic plant operates hinges upon the understanding of how the computer correlates such variable factors as the Btu (British thermal unit) characteristics of the fuel, combustion efficiency, steam flow, velocities, temperature, air pressures, and water conditions as well as makes hundreds of safety checks. Only then can it go ahead with its overall job of finding the optimum operating condition under prevailing consumption levels and bringing about desired ends by adjusting controls.

Power generating with closed-loop control systems is practiced, for instance, at the Louisiana Power and Light Company's plant near New Orleans. The computer not only starts up the plant and keeps it operating at optimum efficiency at any desired output level but also shuts it down when warranted. A computer, being hooked up with all the instruments, takes its readings—no matter how remote the instruments themselves may be—directly from the automatic subsystems.

At the Great Lakes Steel Company, a computer controls hot strip operations. The sensory instruments, depending on customer requirements, could send the appropriate information to the computer from among 113 temperatures, 4 fuel-air ratios, 63 pressures (water, stack, roll balance), 40 positions, 12 speeds, 4 product dimensions, and 1 weight requirement. The computer will, in turn, inform the muscle instruments how to set speed controls, screw down settings, set alarms, etc. to customer specifications in performing the operations.

PARTIAL AUTOMATION[4]

It has already been indicated that most plants have some degree of automation and that very few plants are operating under closed-loop control. The reason may lie in the fact that some types of production may still be cheaper by ordinary mass-production methods where the product moves down a production line and human beings perform the work at various work stations. Of course, some of the operations along the production line may be adapted to automation. In that case, automated operations will be intermingled with customary mass-production methods. A case in point is the Plymouth engine plant, where production is half continuous and half automated.

As shown in Fig. 14-8, work on the engines begins on one side of the plant with cylinder head and block fabrication and work on the various other component parts, and the completed engines are assembled and tested, just before they are shipped, on the other side of the plant. The engine assembly line, is supplied with engine components by the subassembly which furnishes the engine head and by the various component subassemblies such as crankshafts, camshafts, flywheels, and manifolds. The incoming materials for the heavier components (blocks, head castings, etc.) enter one end of the plant and all other components enter the stream of production on the other end.

Figure 14-9 shows the hot-test line, where new engines are tested fully automatically. As the engines come into the testing area on conveyors, an engine is taken into an empty test stand automatically and, equally in automatic fashion, is hooked up to water, gasoline, oil, and electric power lines. When all these are attached without human intervention, an air motor starts the engine and tests it in 20 minutes.

The reasoning behind the conversion of Plymouth Engine Plant to automatic production is that production is speeded up and the costs of engine building are reduced substantially.

The fact that a plant is partially automated may not be as surprising as the work which lies behind an attempt to automate. A large number of technical problems will precede actual operations in the same manner as the layout of a continuously operating production line. The exception is that here a considerably greater amount of thought and care is needed to make the plant perform with precision and rapidity unmatched in human performance.

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[4] Based on C. J. Demick, "An Application of Automation," *Advanced Management,* May, 1956.

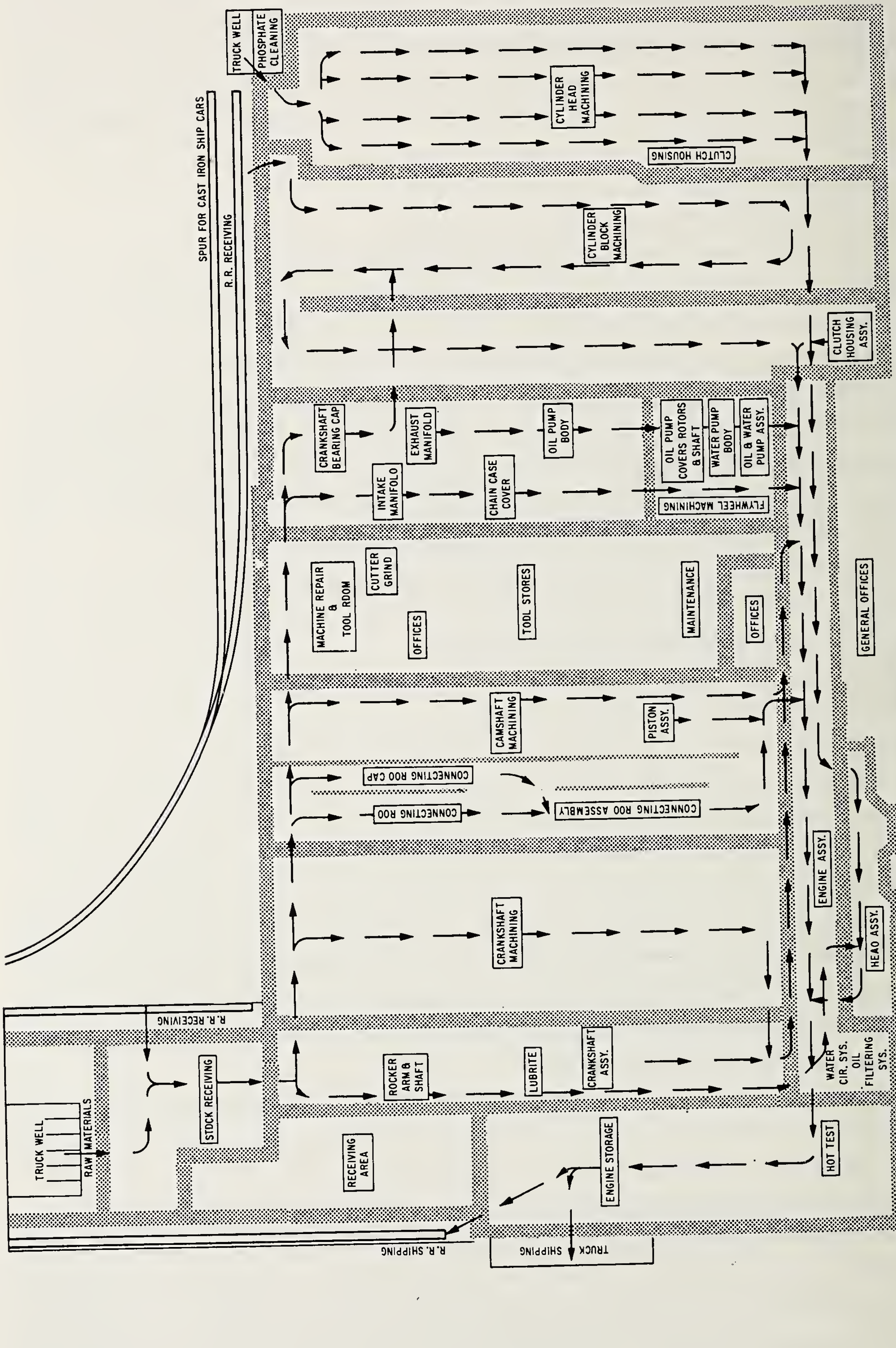

FIG. 14-8. A schematic diagram of the Plymouth V-8 engine plant, showing flow of materials throughout the installation. (Courtesy of Chrysler Corp.)

To get a high-quality product, precision had to be built into the equipment and, as a result, it can build quality into the engines. Every machine had to be designed to detect and correct errors in its own performance and to indicate to men which of the machine components is producing the error. At the same time, all sorts of cost components had to be considered to discover all savings possibilities both in the area of production itself and in the fringe areas of maintenance, repair, downtime on machines, scrappage, and trouble shooting.

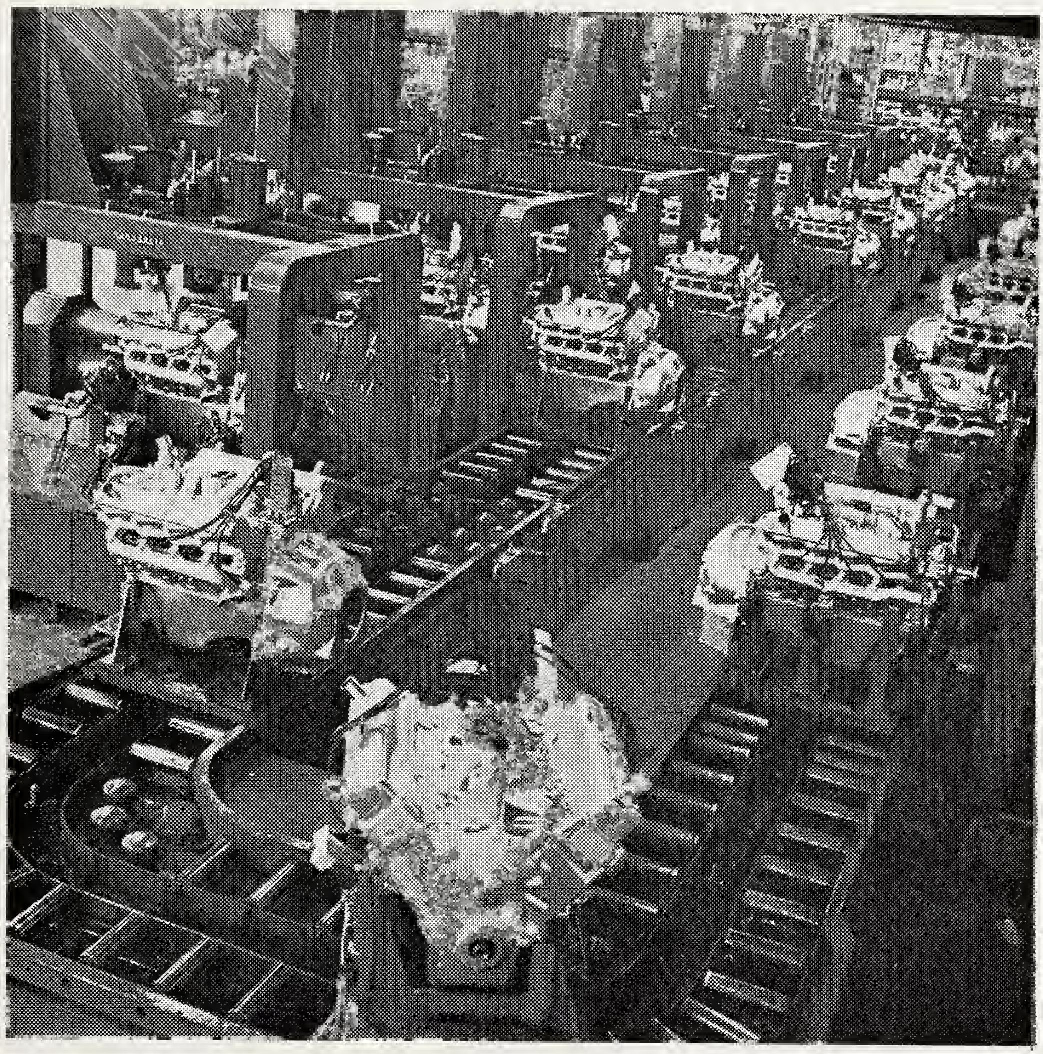

Fig. 14-9. Automatic testing of engines. (Courtesy of Chrysler Corp.)

Although the engine plant in question is only partially automated, it contains a far greater amount of automatic equipment than is found in most plants. Those stations which are still handled by human beings are so handled because in certain areas there is no reason to replace the workmen. Certain things can better be performed by feel, observation, and manual handling. But probably the most important consideration is that automatic devices would cost more to operate than the combined effort of man and machine. If a change in the engine had to be introduced often, the automatic machine would become obsolete immediately, but if a multipurpose machine is assigned to a work station operated by a workman, the change can be made without added capital cost. The inspector's job is also not automated, but for a different reason. Thus, for instance, the sound of the motor may vary somewhat, but when a motor runs perfectly, an inspector can hear it. He also will hear when the motor runs irregularly. Thus, human judgment and skill cannot be replaced. In other cases, such as putting rods in place and attaining right clearances and adjustments as far as tappets are concerned, the feel and judgment of a skilled operator are invaluable.

There are, however, machines which operate so much better and faster than an operator-monitored machine that their introduction is warranted under any circumstances. A machine which gages each part as it is produced and automatically resets the cutting tools to compensate for tool wear can produce quality goods faster and better than human beings could ever produce them. In addition, when the cutting tools have been worn down to a certain predetermined limit, the machine replaces (without human intervention) the worn-out cutting tools with sharp ones and with a precision that human beings could not duplicate. Automatically loading parts onto a machine and automatically unloading them as they are finished are areas in which man is less efficient than a machine. But probably more important is the fact that a nut runner which tightens head bolts hour after hour to exactly the right torque will do so not only on this year's model, but on models in years to come. Thus, all the above operations can be performed faster not only on any given year's model, but at any time in the future. Those operations which are done in the same way year after year lend themselves to automation, and therefore the obsolescence factor would be equal to zero, at least as far as technological obsolescence is concerned.

Actually, in order to decide which operation can be done costwise and otherwise better with the help of human beings and which can be done cheaper and better with the help of automatic devices, a careful cost calculation is in order. The cost calculation starts with the time study data because through the time factor the cost factor can also be ascertained. An estimated time requirement with the conventional method and the automatic method can give an excellent point of departure for cost considerations.

So far, feasibility has been expressed in terms of costs. But cost may not be the only guide. The adaptability of the product may be another important factor as far as the decision whether to automate operations or retain the conventional mass-production technique is concerned. Process and design problems must be carefully and collectively solved. Frequently, complaints used to be heard in the automobile industry that the body designers requested impossible things from the stamping plants. Although the stamping plant always solves the "impossible" problems, the fact that one group felt no loyalty to the other indicates that each of the different engineering groups felt that its area was a separate domain. In automation these groups must evidently work together.

Before contemplating automation, the designers must ask themselves whether the product can be designed in such a manner that it lends itself to automatic processes. The conventional design must often be redone. Hand in hand with the redesigning of parts go process and equipment redesign. No design engineer could, for instance, afford not to take capabilities of the most advanced stamping facilities into consideration. When the body designer drafts his design for a new body, he is reasonably sure that it can be mass-produced. Of course, prior to making trial runs or samples, the original design is brought to the attention of the production group for clearance. But all things are matters of degree. In fact all engineers, regardless of their specialties, work together in the strictest sense of the word. The communication between product designers and plant designers is better today than ever before. During the construction of the Plymouth Engine Plant this cooperation and communication was particularly amenable.

When the decision to build this plant was reached, an open line of communication between the engineers who were designing the engine and those who were laying out the plant (mostly industrial engineers) was established by putting all the men in the same office. When one group decided, for instance, that the engine blocks should be provided with lugs of a certain kind in order to permit palletizing, they turned to the other group to find out whether there was a technical difficulty involved in providing the lugs. When the production group decided that, in order to roll the pistons in troughs, a redesign was necessary, they explained their need and the product engineers redesigned the pistons. Similar changes were made on dozens of engine parts to provide for automatic locating, turning, or moving. The designer, the plant layout man, the time study expert, and the machine designer must evidently work side by side to make automatic production possible.

Synchronization of work stations is among the greatest of problems in automation. In ordinary large-scale production using the conventional method, the product customarily moves from machine to machine. At each work station an employee must clamp the workpiece into the machine before the operation can be performed. Under such conditions it is very difficult to hold close-to-perfect alignment between various cutting operations on any given machined part. When the various holes must be bored, drilled, reamed, and honed in a workpiece at more than one station, the holes must be held in perfect alignment with each other. But, because of these multiple moves, it is difficult to avoid inaccuracies. The fact is that at every positioning tiny variations occur. Even an error of only 1/2000 inch will cause the various holes on the casting to get out of balance relative to one another. These difficulties in automatic fabrication must be solved prior to designing the machine.

At Plymouth, these difficulties were overcome by combining operations which each machine would perform. For instance, on the cylinder-block line, one four-way boring machine would finish-bore the main bearings, camshaft bushings, distributor shaft hole, the oil pump shaft holes, and the dowel holes at the end of the block, and, simultaneously, it would mill the oil pump pad. Since all six operations are performed simultaneously with one machine, the relation of each dimension to all the others can be held to a near-perfect tolerance.

The practice of performing multiple operations on as few machines as possible is not new. Not so long ago, for instance, 12 milling machines were required to work the flat surfaces of engine blocks at the rate of 110 per hour. Today, two broaches shave all surfaces at the rate of 140 an hour, in addition to eliminating all the transportation from one machine to the next.

Some of the typical automatic features of the Plymouth Plant are observable at the testing station. Of course, the testing process begins at the foundry. If the casting itself is pretty close in tolerance, the operations on the automatic production line are almost certain to be perfect. Any casting that exceeds the specified dimensional limits is automatically ejected at the testing station. The raw material is evidently brought in line with the requirement of the automatic production line.

In making the decision to use broaches rather than milling machines for flat surfaces (on cylinder blocks and heads), Plymouth engineers made certain that the quality of the casting which reaches the automatic production line is controlled both as to dimensions and as to uniformity of metal hardness. While broaching gives a greater number of production units per hour than milling, it precipitates more breakages and downtime. The above-mentioned testing eliminated the principal source of downtime by eliminating the tool breakage resulting from occasional "hard spots" in the castings.

Throughout the Plymouth plant there are automatic testing devices to make sure that parts have been properly machined. Following every drilling operation in the head and block lines, for instance, there are automatic probing stations equipped with feeler gages to ensure that all holes have been machined to the right depth and that they are free of broken tools. If there is no hole where there should be one, the machine automatically stops.

After machining operations, air gages are used to check dimensions. If tolerances are exceeded, respective machine operators are informed immediately by means of colored lights at their control panels. At the same time, one of the three lights on the machine goes on automatically and informs tool men in the working area of the trouble so that it can be remedied in a matter of minutes. Gages are located at several strategic points to indicate, also by means of colored lights, that holes are approaching the out-of-tolerance range.

From a partial automation of the engine line at Plymouth resulted a substantial increase of engine output without adding to the labor force; costs of production went down and the quality of the engines has improved substantially.

COMPLETE AUTOMATION WITHOUT COMPUTER CONTROL

In industries where the product is uniform, automation has been in use for many years. Light bulbs, for instance, are assembled from component parts, vacuum-sealed, and tested automatically. In case of short circuit, the bulb is automatically ejected from the automatic assembly line. Thus, practically no human hands touch the light bulbs as they move through the production line. In the bottling industry, automatic bottling, labeling, and sealing of the bottles takes place. Employees are needed only at the beginning and the end of the automatic bottling line. In the beer-bottling industry, testing also takes place with an electric eye which ejects the bottle automatically if impurities in the beer are detected.

In the packaging field, automation has been employed for many years. Butter, for instance, is wrapped and packaged without human intervention. In the cigarette industry, everything is done by automatic machinery even prior to packaging. Cigarettes are automatically formed in long sticks, chopped up, packaged, cellophane wrapped, etc.

Marathon Southern, at Naheola, Alabama, recently built a 530-foot long machine, Fig. 14-10, for the production of high-quality paperboard. The automatic papermaking machine can make stock for cups, food packages, and milk and other containers at a rate of approximately 300 tons per day with only three or four men at the control panels.

AUTOMATION AND PRODUCTION CONTROL

In automatic production, whether closed-loop, open-loop, or numerical control, the production control function is most likely also automated. If a computer is available, it can also be used to take care of the paper work associated with production. In other words, it will keep records about output and depletion of raw materials and component parts and print purchase requisitions as soon as preestablished inventory positions are reached. In some instances, the sales forecast (when it is revised or updated, the master is changed) automatically sets in motion the automatic equipment and shuts it down when maximum finished inventory levels are achieved. In numerically controlled automation, the computer is not needed, but it can, if it is available, facilitate the preparation of the tape inasmuch as the coding of dimensions, feeds, speeds, and other technical matters which the machine tools must know in order to function can be programmed into the computer.

PROGRAMMING THE COMPUTER FOR PRODUCTION CONTROL

The programming *is* the production control work. The routine paper work associated with production control is carried out automatically by either a computer or a data-processing machine.

In intermittent production, the computer might be engaged to calculate the *best route* for any given job based on different efficiencies. The formula, which will be given in the next chapter, is placed into the memory unit of the computer, which will duly recall it upon receiving raw information. Otherwise, the output figures operation by operation might be fed to the machine, which can tabulate the in-process inventory and give an accurate record of where the product is at any given time. It is, however, unlikely that intermittent manufacturers will engage the computer or data-processing machine, in view of the fact that the routine computations are too few to make computer control pay for itself.

Repetitive and continuous production lend themselves excellently to automatic production control. During the programming stage, economic runs are determined, maximum and minimum inventory levels are established, processes (route sheet information) are fed into the memory unit, parts lists are established, etc. As finished inventories are reduced, or as parts are reduced in assembly industries, the computer or data-processing machine automatically prints out a shop order or a purchase order, depending on whether the item is purchased or manufactured. The lead times are a part of the information necessary to program a computer for this kind of work. Any time the lead time changes, as for example, the lead time for steel delivery varies widely from 8 months to 4 weeks, the program must be adjusted. As long as everything is kept up to date, the computer or data-processing machine can follow the coded and programmed instructions and schedule suppliers' deliveries and quantities of raw material based on economic

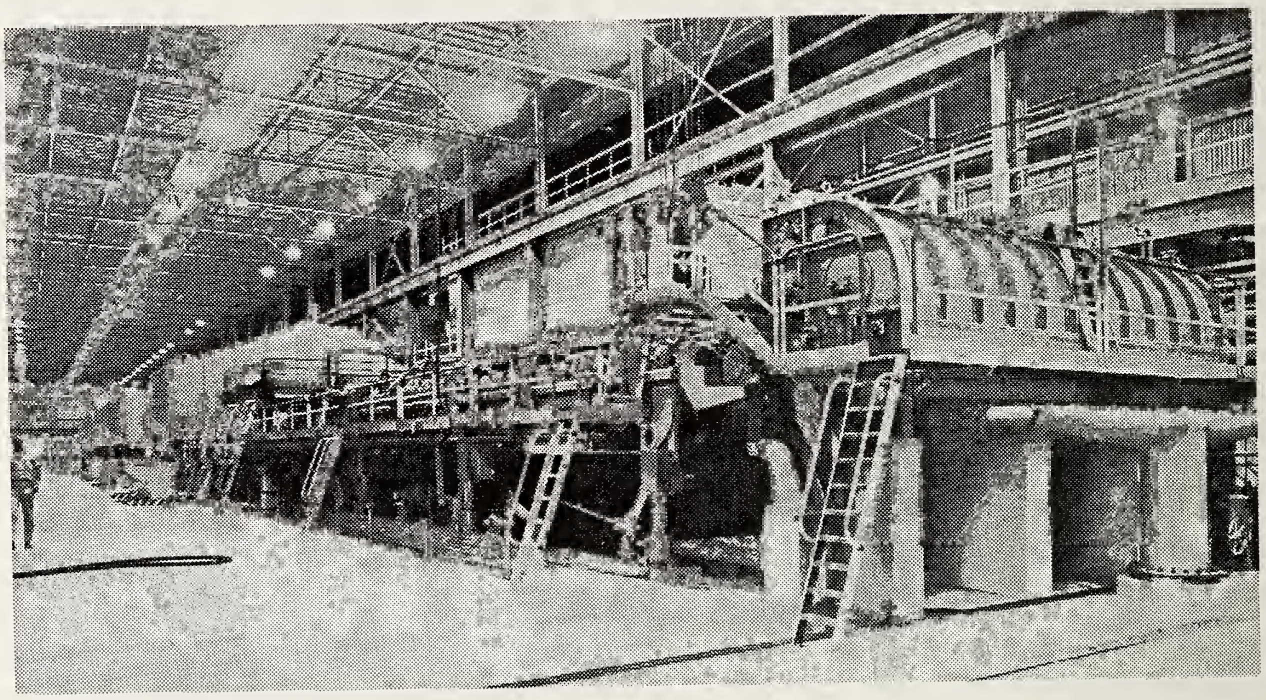

FIG. 14-10. Automatic papermaking machine. (Courtesy of American Can Co.)

purchase sizes or economic runs so that the raw materials will always be available as production requires.

There is a linear relationship between usage and output. Thus, for instance, when output is 100 cars, 200 headlights, 500 tires, and so on are automatically deducted from the inventory. Now when minimum inventories on headlights and tires are reached, the purchase orders are automatically printed out and, by the time the last unit in the stockroom leaves the shelf, the new supply arrives.

Again, how these things are handled depends largely on whether the product is made in repetitive production lots or continuously. In continuous production, the sales forecast or its revision can control the inflow of material automatically. When the forecast is changed, every derivative decision is automatically changed. In other words, a revision downward would automatically slow down depletions in inventory and would dampen acquisitions of parts and components; conversely, better than expected sales will accelerate the procedure.

SUMMARY

Conversion Problems in Automation

Automation, like mechanization, is a necessity forced upon a manufacturer by competition. Competition tends to reduce the profit margin to intolerably low levels at the same time that costs of production—particularly the labor costs—keep climbing. To combat rising labor cost and to widen the profit margin in a highly competitive economy, companies consider the possibility of automation.

Despite its apparent advantages, automation is not always feasible. Whereas automation is applicable in the technological sense, if the economies of production is unfavorable, automation could cause more headaches than it cures. In other words, in order to carry out a program of automation successfully, certain prerequisites must be met. These prerequisites lie primarily in the field of marketing rather than technology; though even the latter might be a sufficient handicap to make automation inadvisable.

The labor cost, including fringe benefits, usually associated with the labor cost factor, are eliminated in automation to a considerable extent. In addition, fluctuations in performance as a result of human frailties are eliminated.

The labor cost is, however, replaced by capital cost. As a matter of fact, the capital cost might be higher than the labor cost which it replaces. Hence, unless the volume of production is large enough to legitimately depreciate the value of the equipment, automation causes greater costs to the enterprise than the potential savings, which can be realized only if the greater output of automatic equipment can be absorbed by the consuming public. Furthermore, it is essential to eliminate both seasonal and cyclical demand fluctuations in order to make automatic equipment pay for itself. The main reason for this is that the equipment can turn out the goods at a fixed rate and cannot be adjusted to widely fluctuating demand conditions. If demand in certain parts of the year is greater than the capacity of the automatic production line, it can be covered either from surplus production of a preceding period or refused.

Making deliveries from stock might or might not be feasible under certain economic conditions. If the in-bank or storage time is long and costly, the savings in production costs might be less than the cost of storage. Therefore, savings resulting from automatic processes might be absorbed by other costs and can under certain circumstances make automation costlier than the conventional large-scale production.

When demand conditions are steady or can be made steady, it is feasible to produce with automatic techniques provided the product lends itself to automatic production. This statement tends to imply that production of only certain items lends itself to automatic production techniques. The reason is that certain basic factors speak against automation. One of them is design. Unless the consumer is satisfied with uniform products throughout the years, automatic production is not feasible.

Consumer acceptance of uniform design over a period of 15 to 30 years, depending on the size of the demand and the life of the equipment, might be an adequate inducement to convert from conventional to automatic production. As a matter of fact, new developments in electronics often make the job-shop type of operation applicable to automatic production. This is done through numerical control.

Design of product and design of the equipment go hand in hand. The equipment must accommodate the product, and vice versa. By its very nature, the engineering planning aspect of automatic production is a team effort. There must be constant communication and cooperation between process engineers, design engineers, and machine design engineers. Also, the time study engineer becomes an extremely important link in the automation process, because a perfect synchronization between operations must be achieved before continuous flow can be transferred to ingenious switching devices, in lieu of being done by the machine operator.

MARKETING PROBLEM

The extraordinary importance of the marketing problem cannot be overemphasized. Automatic production lines are extremely productive. Operations which would require 100 work stations in the conventional production line type of operation can be reduced to a 10-machine production line. Instead of a hundred operators, two might be needed—one at the beginning and one at the end of the production line. The main task of the operator is to see to it that raw materials are fed to the machines and goods are taken off at the end of the production line. Of course, maintenance men might have increasing importance, since profitability of automatic operations depends largely on the perfect functioning of the line. It stands to reason that a production line which never stops and performs a series of operations in 50 minutes instead of 5 hours is capable of turning out more goods in shorter time than current market demand would warrant. Hence, it is essential to raise demand through the various marketing channels prior to converting the plant from conventional to automatic techniques.

In the past, only those companies which were assured a growing market automated their facilities. The automobile companies, the process industries, and the bottling industries were able to convert to automation because the consumers were not all too specific about the design they wanted and because the volume warranted the introduction of automated equipment. It should be noted, however, that only certain automobile parts lend themselves to automatic production. When the design must often be changed to meet consumer preferences, automation would be more costly than the conventional continuous production method.

In view of the importance of a steady demand for a uniform style, it is up to marketing management to stabilize the consumer demand so that output is fully absorbed by consumption. The ideal situation and certainly the one which makes automation feasible, is that plant capacity is equal to demand. The next function is to pace demand through marketing and sales promotion devices at the same rate as the goods are turned out.

Once the marketing problem is worked out and brought into line with the technical capability of automatic lines, little stands in the way of profitable operations. Automatic production operates at low unit cost provided a steady utilization of equipment takes place. Idleness in automatic plants might be extremely costly and can make automatic production systems less profitable than the conventional continuous production line.

SIMPLICITY OF CONTROL

Automatic production lines making standard or nonstandard products are controlled by instruments rather than by people. The machine operator is replaced by sensory devices which set both the machines and a myriad of conveyor systems into motion. Materials handling and the number of operations are reduced to the absolute minimum.

In view of the costly nature of automatic equipment, efforts were made in recent years to make automatic equipment more versatile than it was originally. The versatility of equipment increases its utilization and thereby prevents equipment obsolescence—otherwise a serious handicap to automation. This development, however, was made possible primarily through computer development. The latter became an integral part of automatic operations. Now that so many different companies produce relatively cheap computers, automation and automatic control of operations, through computers or data-processing machines gains acceptance. The feasibility of automation grows in proportion to the acceptance of computer use.

Servomechanism might control the position of cutting tools and open or shut valves or other parts of the equipment as well as control the whole flow of production of the automatic line. In case of closed-loop control, automatic equipment can also be built so that it corrects errors by receiving instructions from the computer if the product seems to be out of tolerance. The computer quickly determines the answer to the problem and directs the adjustment of the machine tool in question. Hence, at the end of the production line, the goods are always of uniform, but above all, acceptable quality.

The control of operations and the associated paper work are done by the computer and the sensory devices connected with it. Hence, the production control work might easily be transferred to the computer. Of course, the production control man is still needed—not for the clerical duties associated with production control, but in the programming end of the computer work.

QUESTIONS

14–1. What is the difference between mechanization and automation?

14–2. In what way does automatic production resemble the continuous production method as described in Chapter 13?

14–3. What are the advantages of automatic production in general?

14–4. When is automation feasible?

14–5. Is automation the best method of combatting high wage rates and cut-throat competition?

14–6. What are the obstacles to automatic production?

14–7. What is the relationship betwen automatic production and marketing?

14–8. What are the cost relationships between automatic production and conventional continuous production on the one hand and intermittent production on the other hand?

14–9. What kind of study should management undertake prior to deciding on automatic production?

14–10. What is the role of the computer in automation a) in open-loop control and b) in closed-loop control?

14–11. What is the relationship between operations research, closed-loop control, and automatic controls over processes?

14–12. What is the task of the programmer in automation with closed-loop control?

14–13. What is numerical control?

14–14. How does numerical control operate?

14–15. Will a progressive automation create a serious unemployment in the American economy?

14–16. What is the function of the computer in numerically controlled automatic production, in production planning and control, and in inventory control?

PROJECTS

14–1. Determine what the computer must know about cement making if a cement manufacturer wants to introduce closed-loop controlled automatic production.

14–2. Based on the following information, determine whether automation is feasible:

a. Only dimensions of the product vary (numerical control is possible).
b. On the average, work stoppages due to strikes causes $5 million damage in lost business, depreciation charges, damage to equipment, etc.
c. Total yearly output approximately matches total yearly plant capacity; during the summer months, the work week averages 30 hours, whereas during the winter and autumn months it averages 50 hours.
d. Labor cost represents approximately 40% of the total costs of production; capital cost, 35%; and material cost, 25%.

14–3. After a successful automation, what changes in the production organization must take place 1) in top management, 2) in staff personnel, 3) in middle management, 4) in operating management? The plant is engaged in the production of one standard item.

14–4. Explain production control in automatic production.

14–5. Define the qualifications of a computer programmer doing production control work in a process industry such as an oil refinery.

CASES

14.1. AMALGAMATED IRON AND STEEL, INC. (PART 2)

A large steel producer in the United States, Amalgamated Iron and Steel, has a large number of basic steel-producing units such as blast, electric, and open-hearth furnaces in addition to rolling and finishing divisions. The company also has direct or indirect interest in ore mines throughout the United States, Canada, Liberia, and Venezuela. The Liberian interest is on a partnership and sharing basis.

Despite the fact that sales and output have been sliding ever since 1955, the company decided to increase its production capacity by improving blast furnace operations and automating rolling and strip mill operations. In order to pass judgment on the matter, it is essential, however, to consider the circumstances under which this decision was reached. Despite the mediocre performance of the past few years when it was a touch and go whether the company would earn enough to cover dividend payments in the usual amount, company management is confident that automation will pay off.

Company management considers the future bright as long as costs can be brought into line with competitive prices relative to foreign-made steel and competitive products such as glass, aluminum, plastics, and cement. It is contended that a moderate reduction in the price of certain steel products for which prices must be reduced to attract customers and holding the price line wherever possible will guarantee adequate sales possibilities. If automation will in fact attain the cost reductions which are expected, profit margins can be widened at the same time. The fact is that plastics, aluminum, cement, and glass compete with steel only on a price basis, and by no means on a quality or suitability basis. Hence, as far as AI&S management can see, efficient steel making is the key to profitability.

According to present plans, all plants in the modernization and automation program will be completed by 1965. It is not expected that there will be a strike before 1964, and by that time most of the mills will operate through automatic facilities. As long as blast and open-hearth or electric furnace output can be stockpiled, the finishing departments can be kept in operation despite an extended strike. Thus, the company hopes to weather even the strike period with considerable success.

During the past few years, as is apparent from the data in the accompanying table, steel markets declined because of the extensive use of competing materials, foreign steel, and declining export markets, in addition to the lower steel requirements of the compact automobiles and depressed business conditions in steel-consuming industries such as oil drilling, pipeline laying, and construction. Most of the decline can, however be halted with substantial productivity increases.

As indicated by the figures in the table, production over the years has increased in every case except steel. Output of plastic materials is up a fat 66% in the period; steel, in contrast is down 15%. The company's share of the market is pretty much the same from year to year, and with the general decline in steel production, sales have fallen off correspondingly.

During the 1960–1961 recession, approximately 50% of the nation's

Comparative Data on Production of Steel and Competing Materials
(Totals in the Table Are in Thousands; Units Are in Net Tons.)

Year	Steel	Aluminum	Plastic	Cement
1961	98,014	2014	3300	60,724
1960	99,282	2014	3072	59,972
1959	93,444	1953	2164	63,282
1958	85,255	1566	2933	58,468
1957	112,715	1648	2259	55,524
1956	115,116	1679	1989	59,408

120 to 150 million tons of steel-producing capacity was idle and during the period 1957–1958 recession nearly as much as this, but the AI&S facilities were only approximately 30% idle. Despite this advantage as compared to the national average, operating profits fell drastically during these years. After the contract settlement of 1962 without a strike, business again declined. In other words, the company expansionary decision takes place under conditions when the steel industry is in its worst shape than since before 1930.

The fact should also be considered that steel capacity is excessive throughout the country because of the wide fluctuations in steel demand. Most plants are geared to peak capacity utilization, yet that capacity is seldom used. Thus, the break-even point is an important decision. With the new steel mills, the break-even point is estimated to be met if and when the plant is able to operate at 73% of capacity all the time.

Some plant facilities are already highly automated, and management does everything in its power to maintain sales despite the existing conditions. So far, in the pipe-production business, discount policies raising the discount rate to jobbers from 3% to 5% have been completely ineffective. As a result, profit margin on pipes has narrowed even more.

The experience with the pipe mills is related here merely to illustrate a situation similar to that which can be expected when the rolling and strip mills are automated. Thus, it might be worthwhile to draw a parallel between the situation in the pipe mill and the rolling and strip mills.

To see the overall situation in steel production, Fig. 1 should be studied carefully. Since automatic production appears to be beneficial only if there is a stability in demand which closely corresponds to the optimum output capacity of the plant, it might be significant to draw certain conclusions on the basis of the chart.

In conventional production, spurts in demand mean that employees must work overtime; but when steel demand is low, employees are laid off. Although a generalization is often misleading, the assumption can be made that approximately 40% of the steel company's costs are made up of labor costs and 60% represents material and capital costs. However, the material costs are relatively small when contrasted to the capital costs. The material cost per ton of steel or ton of fabricated steel products varies to such an extent that no attempt is made here to give a figure. The cost considerations are important, because when all plants currently in construction or on the drawing board are completed and in operation, approximately 50% of the company's facilities will be the more efficient automatic type. While it is intended to run all automatic plants always at high capacity, the utilization of the obsolete or less efficient plants will depend on demand conditions. Most likely, the plants with lower capital costs and high labor cost will be shut down rather than let those plants with high capital costs stay idle or operate inefficiently. Thus, the company will be able to save on labor cost, but the capital cost will presumably go on.

The experience with the first automatic mill was favorable during a recent recession. The company was able to keep this plant in optimum operating level, despite a substantial fall in demand. Although most plants operated with a loss, the automatic mill operated efficiently and was able to recover some of the losses.

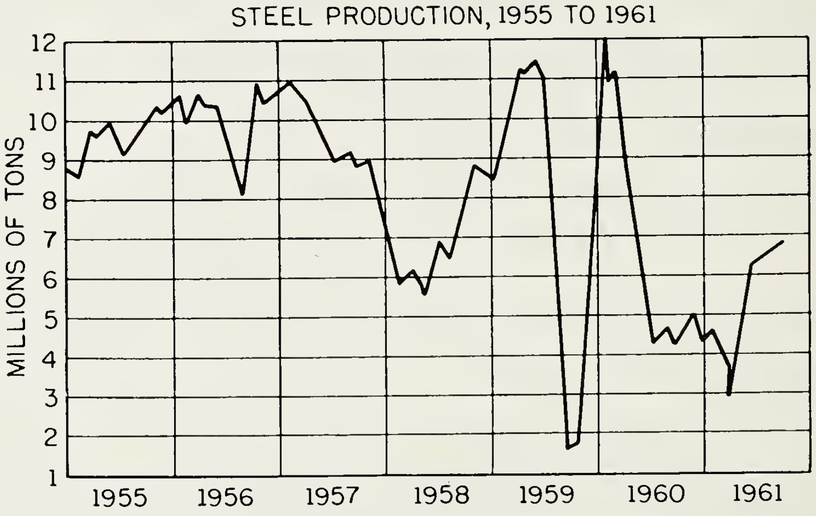

Fig. 1

The labor cost factor must also be looked at carefully. The plant where labor is needed depends largely on labor cost and availability. In the automatic facilities, this cost is nearly fully eliminated, but of course in place of it comes the higher capital cost. Nevertheless, if demand is adequate, the capital cost can easily be recovered as a result of the greater profit margins.

The whole steel industry is beset by labor practices which drive wage rates and labor costs considerably higher than is competitively desirable. Although the company's efforts to automate the strip mill and rolling mill facilities is not aimed at elimination of labor per se, it is apparent that it will have that effect. The labor cost which can be saved is, of course, quite substantial, because the wage rate paid by Amalgamated is considerably higher than the average paid in other branches of industry. Specifically, the average rate obtained by Amalgamated workers is 88 cents more than the national average. Although the labor cost is not the only saving which automation will bring about, it is significant because in the past years wages rose faster than labor productivity. This is illustrated by Fig. 2. The contract settlement in 1962 and the steel-strike-accompanied settlement in 1960 resulted in relatively small cost increase. Nevertheless, the rise in 1960 represents 39 cents and in 1962 approximately 10 cents per year. The 1956 settlement, in contrast, was 81 cents. Although costs, and particularly the labor cost, were constantly rising, the keen competition did not permit raising the price in order to absorb the higher operating costs. The next steel settlement becomes significant, not because of the overall effect on company operations, but primarily because the labor union tries to block the company's automation attempts.

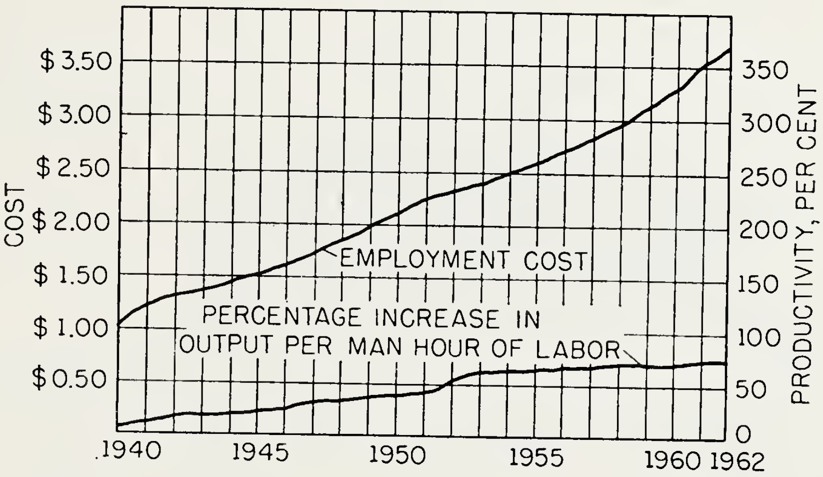

Fig. 2

During a recent convention, the spokesman of the steel workers union stated that "the union will fight the unbridled automation attempts of the company when negotiations open in 1964. In addition to a wage increase and increase in fringe benefits, we will seek iron-clad guarantees on job security, particularly a protection against the various schemes for further automation of strip and rolling mill operations. As far as USWA is concerned, gadgets or no gadgets, the steel workers will stay on the payroll."

In order to maintain the competitive position of Amalgamated Iron and Steel, automation became a necessity. All projects were carefully selected and decided upon after an exhaustive analysis of the competitive abilities of each plant matched against the requirements of customers of the company. While the company's facilities measured up well when compared with those of competitors, there were areas in which efficiency could be raised without impairing versatility. The conversion from conventional to automatic production is the company's answer to the steadily rising labor and capital cost problems in the belief that the company can successfully reduce operating costs by raising productivity, which has been steadily deteriorating during the past 5 years. This will also enable the company to reduce costs and prices where necessary to compete with aluminum and plastics as well as with the European steel, produced at one-quarter the labor cost at Amalgamated.

Despite constant managerial effort, company profitability did not keep pace with growth in America. According to Fig. 3, company profits after taxes were higher in 1950 than in 1960, when sales were substantially higher.

Why Amalgamated Iron and Steel, Inc. fared worse than some of the other important companies has often been debated, particularly because it operated at a higher rate of capacity utilization than some others. Obviously, owing to the severe competition, profit margins over the years became paper thin at the same time that taxes, labor costs, and replacement costs went up. The latter is significant, because replacement costs (which were higher than depreciation allowances) had also to be covered from profits. The depreciation regulations are obsolete in the sense that they are based on an "inflation-free" economy. Thus, the theory that equipment reproduces itself just does not hold true. The economic life assigned to a new machine by the Internal Revenue Service is fully unrealistic in its present form.[5] Only part of the replacement cost is recovered each year, because the equipment, which might have an economic life of 40 years, becomes obsolete in 20 years. Thus, by the time it is ready for the scrap heap, only half of its original cost has been recovered. Furthermore, a blast furnace that cost \$8 million in 1945 today costs at least \$26 million. Among other things, this inadequacy of the depreciation allowance has depressed company earnings over the years.

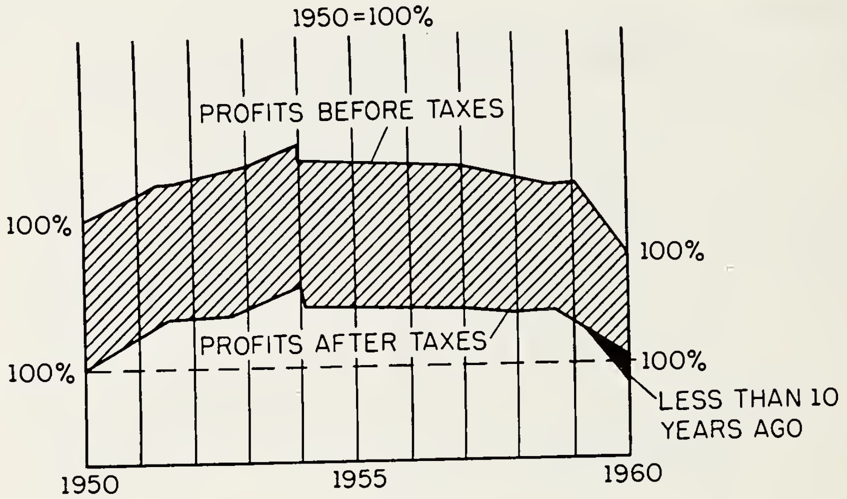

FIG. 3

Automation in the strip rolling mills means that the rolls will be regulated by computers. The instructions which raise or lower the rolls will be given to the machines by a perforated tape. The perforations indicate customer requirements and will adjust the rolls to meet customer specifications. Accordingly, the tape will automatically lift or lower rolls in the mill stands as hot ingots or cold coils move back and forth, growing thinner and longer with each pass. In conventional rolling the same thing takes place. Conventionally however, several men work less accurate hand controls at a much slower pace. Thus, in addition to having greater speed, tape-operated rolling and strip mills will turn out a more uniform product and reduce waste and wear and tear on the equipment. One ingot after the other is being rolled, that is, flattened, as if all were of uniform gage, but of course each ingot might be rolled according to different customer specifications. A tremendous advantage, of course, is that there is no interruption in operations. The strip mills will, in a similar manner, be able to make all standard grades of carbon steel and flat-rolled products up to finished widths of 48 inches. The widths and gages of the steel rolled to given flatness will be considerably more uniform than they would be if an operator visually checked the instruments. The computer will compare the pressure, the heat, and the composite of the ingot and dozens of other elements with one another and will make the rolls always move so as to make a perfect product.

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[5] The recently revised schedules are more realistic, but they are still a far cry from being correct.

Questions. Amalgamated Iron and Steel, Inc. has embarked upon an automation program in the apparent belief that this is the only answer to the profit squeeze and price competition which have been plaguing the company in the past few years. The general description of the situation and the economic setting within which the decision to automate was made is given in the case. On the basis of this description, the student must decide whether automation is the sensible answer or whether management should have chosen another course of action. The analysis should follow this general pattern:

1. What factors precipitated Amalgamated Iron and Steel's decision to build these plants and make the improvements indicated in the case? (This corresponds to the symptom-cause analysis).
2. Do you think that automation is going to solve the company's problems? Explain your answer by supporting your statement with logical facts.
3. Do you think that all prerequisites to a successful automation are present? If so, explain why this decision seems wise to you.
4. What dangers are apparent in the automation efforts of AI&S? Explain them by the cost and saving function.
5. Are strip and rolling mill operations suitable to automatic operations?
6. In light of the economic conditions, the changing nature of steel demand, and the development of substitutes, do you honestly believe that the company should have gambled on automation at this time?
7. What difficulties do you foresee in this automation case?
8. List the errors, if any, which the company made in considering this conversion.

14–2. Danubia Refinery Company

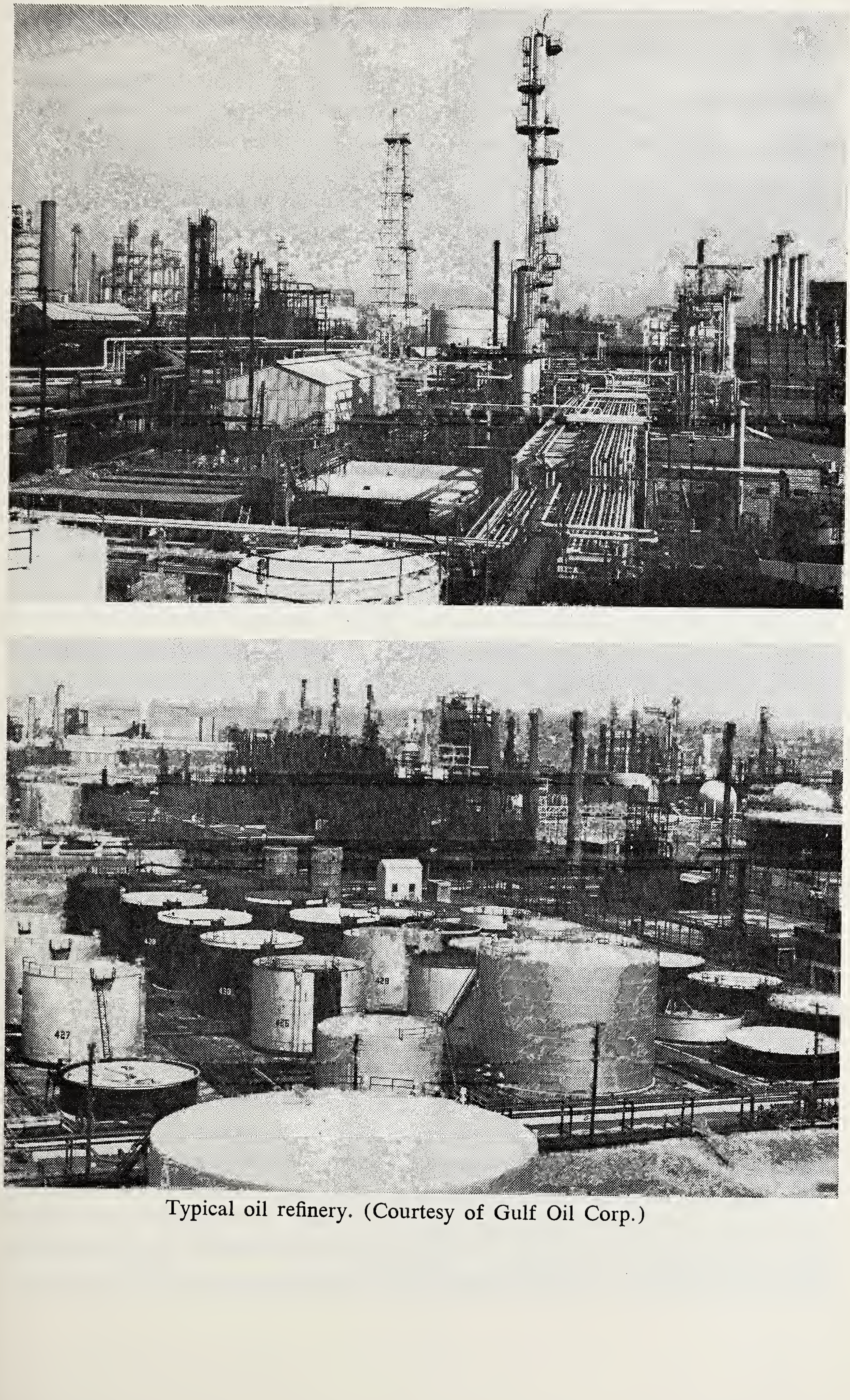
A subsidiary of a large oil company, Danubia Refinery Company was one of the first oil firms to automate its refinery operations. At first one plant was automated on an experimental basis. Danubia refineries are located in strategic points throughout the United States and in eight foreign countries. The crude or semirefined oil is transported to the point of use in pipelines. Refinery facilities include towers for the distillation of crude oil and tanks for catalytic cracking and reforming, product testing, blending, and shipping. Two views of a typical refinery are shown in the accompanying illustration.

When the oil boom after the Korean War subsided, Danubia Refinery Company, along with the rest of the industry, found it extremely difficult to break even, and the company's competitive ability seemed to be endangered. This was particularly true in the East Coast section of Canada. Since the Canadian territory promised good possibilities for a steady market, consideration was given to the construction of an automatic refinery unit with a relatively small capacity of 15,000 barrels a day. Company engineers contended that, if in constant use, the plant would be adequate in size to meet demand and, at the same time, operations would be efficient enough to compete with much larger refineries in the area on a unit cost basis.

The plant was completed and in use by 1958. Although a fully automatic plant, the refinery was laid out in such a manner that in case of mechanical failure a standby crew, working as a unit, could operate and control the entire refinery from one spot. The controls were automatic, but still 10 men per shift were on duty to see to it that everything was in tip-top shape. Owing to the size of the plant, however, repair services were performed by an outside contractor. The company contended that it was considerably cheaper to hire a contractor for maintenance purposes than to have one's own maintenance department. Thus, the 10 men were in a sense men for emergency purposes and could do some preventive maintenance rather than simply stand by to run the plant if necessary.

In the "ordinary sense," demand for the refinery's output exceeded overall refinery capacity. To counterbalance this handicap, the company's one-man production control department used the "incremental throughput" method of scheduling refinery runs.

According to this method of scheduling, in contrast to customary practice, continuous operations for 24 hours of the day could be maintained to use up *all* the incoming supply of crude oil, rather than base production on consumer demand for different grades and types of oils. Thus, stop and go in refinery operations was largely eliminated. Generally speaking, refineries operate as job shops in the sense that they supply different types of gasoline and oil products after the orders are received. The Danubia refinery, however, produced oil without precisely knowing the demand conditions for different



Typical oil refinery. (Courtesy of Gulf Oil Corp.)

products. As a result, however, the plant could operate with unusually great success. Thus, profits were highly satisfactory.

Refineries receive different crude oils, and out of the oil they make whatever order is on the books. But not every oil is good for every order. Thus, until and unless the chemical composite of the crude oil is suitable, the order cannot be filled. Depending on its origin, the crude oil tends to contain different chemical elements. And, in turn, the chemical composite of the crude determines the production process, that is, heat, pressure, length of distillation time, and reaction time.

Since the company used a computer to run the "shop," it was essential to know the chemical composite of the crude. As the crude oil came into the plant, a chemical analysis determined its composition. Once the composition was known, the preprogrammed computer knew what must be done to get the most yield out of the crude. Thus, when the computer was supplied with information on chemical characteristics, crude densities, and foreign elements, it determined which kind of oil product should be turned out. When later a different crude oil came in, changes in the variable elements necessitated a recomputation. Based on the new data, the computer determined the new process. Obviously, in order to do so, the computer had to be programmed prior to operations. In other words, the model was set up in such a way that it produced a result from the data it received. The second use of the computer was probably more important than the first, although neither of the two uses means anything by itself.

The tedious programming work required collection of precise information about relationships between a control setting and the instrument reading. In turn, the chemical composite determined the pressure, the required heat levels and duration, and many other processing relationships. The program, modeled into the computer for any kind of crude oil composite, was based on knowledge of chemical reactions under heat, pressure, and time conditions. This in turn was derived from theoretical knowledge and empirically established refinery experiences. When the chemical composite of the crude was one of dozens of combinations, the control settings had to be turned accordingly. This was done automatically by the computer.

The computer was hooked up to a series of instrument panels, and it automatically took off the readings from the control instruments. A further comparison between the chemical composite of the crude oil and the instrument readings gave the answer to the processing problem—that is, how to get the best yield out of the crude oil. Through muscle instruments, the computer automatically adjusted the pressures, heat conditions, and other elements necessary to production. Ordinarily, employees had to operate these controls by hand on the basis of their knowledge of chemical and operational relationships. Since there were dozens of instruments which had to be read continuously, the adjustment was also continuous. With human control of the refinery, however, the production was never precise. With computer control everything was under control all the time.

The refinery operations are basically distillation processes. The separation of oil particles largely depends on pressures and temperatures in the distillation towers and later in the cracking tanks. As the heterogeneous crude oil came in, the chemical analysis quickly determined the composite, which, through the computer, automatically matched the heat and pressure requirements appropriate to the specific crude oil distillation, chemical cracking, or combination of the two. In conjunction with the above, one ought to know that certain hydrocarbons (a series of compounds of carbon and hydrogen contained in the crude oil) vaporize at lower temperatures than some other, heavier chemical composites. Thus, for instance, gasoline—since it contains relatively few and light hydrocarbons—would evaporate first within a predetermined period of time and heat level. Even though the evaporation process segregates gasoline from heavier compounds, each compound of heavier-gage oil can be refined again and again. In other words, the remnants can be sent through the same distillation process several times to gain at each recirculation additional yield. Oils must be redistilled many times to attain the necessary closeness of separation. To make the process continuous, the Quebec plant was built around a pipe still as well as a fractionating tower. Thus, the oil was always heated to the most appropriate temperature to induce vaporization of the most vaporizable fractions at once. Unless the chemical analysis was wrong, the computer did establish the best thermostatic and pressure settings to make the process economical. At different levels of this tower, vapor had to be scientifically cooled and condensed in accordance with weight classification in an immediate succession. Accordingly, a series of different grades of petroleum products was produced on a descending scale. At selected levels, liquids were drawn off through automatically operated valves. These valves were set into motion via some muscle instruments connected with the computer.

The Quebec plant was also equipped with a cracking station, primarily to increase the yield. The residue from the refinery tower, or the gasoline distillation process, was led into the cracking station. Cracking, a chemical method of rearranging the molecular structure of the material in the cracking reactor, increased the yield gained from each gallon of crude oil.

Technically speaking, cracking involves synthetic as well as analytic methods. The cracking which takes place in the reactor (a tank connected with all sorts of pipes), breaks up some of the heavy molecular structures of the petroleum products into lighter ones that contain fewer carbon atoms in the molecular chain. The opposite is also done. Light gases when combined with other chemicals can be made heavier to yield additional gasoline or other high-grade petroleum products. Gases which accumulated in the top of the tower had to be combined with other chemicals (usually with gases) to form heavier molecules and become condensible at given temperature levels. The latter, although also done in the reactor, is called not cracking but polymerization and alkylation. Thus, the reactor can either do cracking or polymerization depending on whether we combine atoms (synthetic process) or take apart molecular structures (analytic process) and recombine them into different molecular chains.

To simplify the above explanation, let us reiterate the refinery process at the Quebec plant. The crude oil, based on a chemical analysis, was automatically classified as to chemical composition. This information was relayed to the computer which automatically set the thermostatic, pressure, and other instruments in the distillery or the cracking tank to yield the most out of every barrel of crude oil. The oil was recirculated as many times as were necessary to separate the crude components into desired fractions.

With the computer-controlled process, setup time in the refinery was not necessary. Although there was still setup time, it was in reality cleaning the reactor when too much dirt (impurities) had accumulated. This, however, has nothing to do with switching from one product to another.

It has already been stated that the crude oil is a heterogeneous mass and that the computer controls the required heat, pressure, and other valve settings either in the distillation tower or in the reactor. By adjusting the controls in accordance with the characteristics of the crude oil, chemical checking, laboratory tests during the process, and allocation of oil to customers can largely be made routine.

The different gasolines and oil products are lead into storage tanks. Effectively, customer orders are filled by blending pitch with flux stock into a specific mix that will yield a product meeting customer requirements. While storage costs are much higher in this system than in conventional oil refining, the savings in processing costs and the better yield per barrel of crude oil more than compensate for the added storage costs.

It should be remarked that the above explanation is a highly oversimplified version of oil refining. Many intermediary processes, such as deasphalting, dewaxing, and lead control are left unexplained.

On the basis of the first experience with the computer-controlled plant at Quebec, the company modernized many of its plants, with the result that the company is capable of producing at least twice as much as its share of the market. (The capacity of the company's various refinery units varies anywhere from 45,000 to 100,000 barrels a day.)

Just about the time the company completed its modernization plans, many other companies engaged in oil refining did the same thing. Thus, by 1960 nearly all of the Danubia Refinery Company's competitors operated some highly efficient automatic plants. Needless to say, price wars were quite frequent, since large surpluses of gasoline and other oil products were stockpiled throughout the United States.

An apparent upshot of the automatic process in refineries is that a large part of the oversupply is in fine oil products. The latter resulted from the practice of producing and selling from stock, rather than producing only specific items in quantities presumably adequate to cover the needs of the consuming public.

Whereas at the Quebec plant demand is just about equal to supply, the same thing is not true in other Danubia Refinery plants. This might result from the fact that the total crude oil output during the past 15 years or so climbed 315 to 320% compared with a rise in demand of only 170%. Coupled with the recent practice of producing refinery products as the crude oil is piped into the plant, the inventory cost is almost equal to the savings brought about by the more efficient closed-loop control including the higher yield per barrel of crude. Production to stock, however, cannot be eliminated (except through high turnover); otherwise, the refinery must return to the old, and considerably less efficient, production methods.

The Danubia Refinery Company does not seem to know how to cope with the problem of inventory depletion. In Ohio, Pennsylvania, Indiana, and Mexico it joined in a price war and it succeeded in reducing its stockpiled gasoline in those areas. Where the inflow of crude oil and the plant can be shut down, production has been curtailed; but in most automatic plants, operations must continue to cover expenses. Although inventories have thus been substantially reduced, the overhead expenses, which by necessity go on, are strangling the company. This, of course, is due to the automatic equipment, which has a considerably higher capital cost than the conventional refinery.

Several additional circumstances have contributed to the misfortunes of the Danubia Refinery Company. At the time the automatic plants were completed, the automobile consumption of gasoline had seriously declined. When money was appropriated and plans were made to build the plants, automobile production was in its all-time peak (1955). At the time, sales forecasting indicated that by 1970 the automobile market would expand substantially. Not only did this not happen at the rate indicated by the forecast, but in 1958 many of the automobile plants converted to the production of the compact cars, which consume approximately half the fuel burned by ordinary cars. The European compact cars flooded both the American and world markets, with the net result that gasoline consumption has seriously declined. The capacity of the Danubia refineries, relative to current demand (and Danubia's share of the total market), were approximately twice current need. The unfortunate federal and state gasoline taxation also contributed to the reduction in consumer demand. At these gasoline prices, that is, Danubia's price plus federal and state taxes, people do not travel by car as much as they would if the price of gasoline were 5 or 10 cents per gallon lower.

During a recent stockholders meeting, the president of Danubia Refinery

Company explained that petroleum demand has, among other things, become more sensitive to the general economy, because 30 to 40% of the fuel sold is burned by business. In the last few years the country has been, on and off, in some stage of recession; and demand in the fuel oil sector has been considerably less than it would be under sustained prosperity.

As a result of the above circumstances and because of the unfortunate timing of automation (i.e., building capacity when demand suddenly declines), profitability of the company has severely declined. Unit costs would have been considerably lower had demand remained at high levels, but with the current demand conditions, the company had greater costs than revenues. For the third time in recent years, in order to conserve capital, dividend payment was not made in October, 1960. Subsequently, the market value of the company's stock reached its 10-year low in November, 1960. Since then a steady improvement has taken place and the company is more confident as far as the future is concerned.

To alleviate the situation, in 1962, the company entered the chemical business and has acquired patent rights to produce certain petrochemicals. The entrance into the ethylene, benzine, and isooctyl alcohol fields means that 10% of the company's refinery capacity will be absorbed by the petrochemical business. In the next 10 years, it is estimated that the petrochemical industry will account for 25% of the business of the company's refineries.

The president of the company closed his statement by saying that, "It is unfortunate that the production costs are, according to our present refinery operations, inextricably interlaced with sales volume. And sales volume has severely declined at the time we doubled our output capacity."

Questions. The case illustrates the problems which management must consider when converting from conventional to automatic production methods.

1. Analyze the company's situation to determine whether automation is responsible for the poor showing, i.e., lack of profitability of the Danubia Refinery Company. Explain.
2. What are the symptoms indicating that the company is in serious financial shape and in related difficulties?
3. List the causes for the symptoms. Segregate industry-wide and company-made problems. That is, to what extent is the company at fault?
4. What remedial action would you suggest?
5. What factors did the company overlook at the time it undertook its automation program?
6. What causes the rise in costs when demand declines in this company?
7. Evaluate the wisdom of automation in oil refinery.

14–3. FRED JOHNES, INC.

Although nearly in receivership back in 1945, Fred Johnes, Inc. is today one of the most profitable industrial meat producers in the United States.

Until the bottom fell out of the meat market after the Second World War, Mr. Fred Johnes was a successful cattle rancher. The sudden drop of meat prices caught him seriously indebted to a local bank. Although the bank was patient, when it saw the hopelessness of Mr. Johnes' financial situation, it took steps to foreclose on the property. Finally, however, a different settlement was made. According to an agreement, the bank holds the large majority of shares in a newly formed corporation.

An attempt to sell the property at the time of this difficulty, 1945, was hindered by the fact that both farm and livestock prices were at their postwar lows. Mr. Fred Johnes, being in serious financial trouble, several times went to the bank to present his ideas to the bank president and bank officers, but without much success. One day, however, he found the 27-year old son of the president ready to listen to his ideas. Fred Johnes convinced the bank not to foreclose, but instead become partner in a very profitable venture. He proposed an incorporation whereby the bank would hold the shares equivalent to his debt to the bank. In turn, the bank would let him operate an "automatic meat factory." "Of course, there is a catch to it," said Mr. Johnes, "and that is, your bank must make another $150,000 investment." Further explanation followed.

Because the idea sounded excellent, the young banker's son, a recent MIT graduate, persuaded his father to incorporate as Johnes suggested. According to the agreement, the bank held the majority of shares of the stock outstanding with the understanding that Fred Johnes has an option on each share of stock at $25 per share over the next 10 years. If the venture turned out to be profitable, the bank would recover not only the original investment (on which payment was defaulted), but would also be able to make a handsome profit.

The meat factory, as Fred Johnes called his plant, would be fully automatic. The cattle would not move, but would stay in designated quarters. Therefore, none of the meat would become tough, and a high-quality beef would be assured. The feed would be transported to each animal through an automatic "feed conveyor" in the same way that, in industrial plants, material is transported to work stations. The feed would contain a healthy mixture of antibiotics, hormones, minerals, and vitamins in addition to certain predetermined calory values. The whole system of feeding, including mixing of the feed, would be performed automatically by a small analog device and a materials-handling system based on the remote-control principle. Periodically, water would be channeled to the feeding stations through conduits. Salt and other minerals would be mixed with the feed.

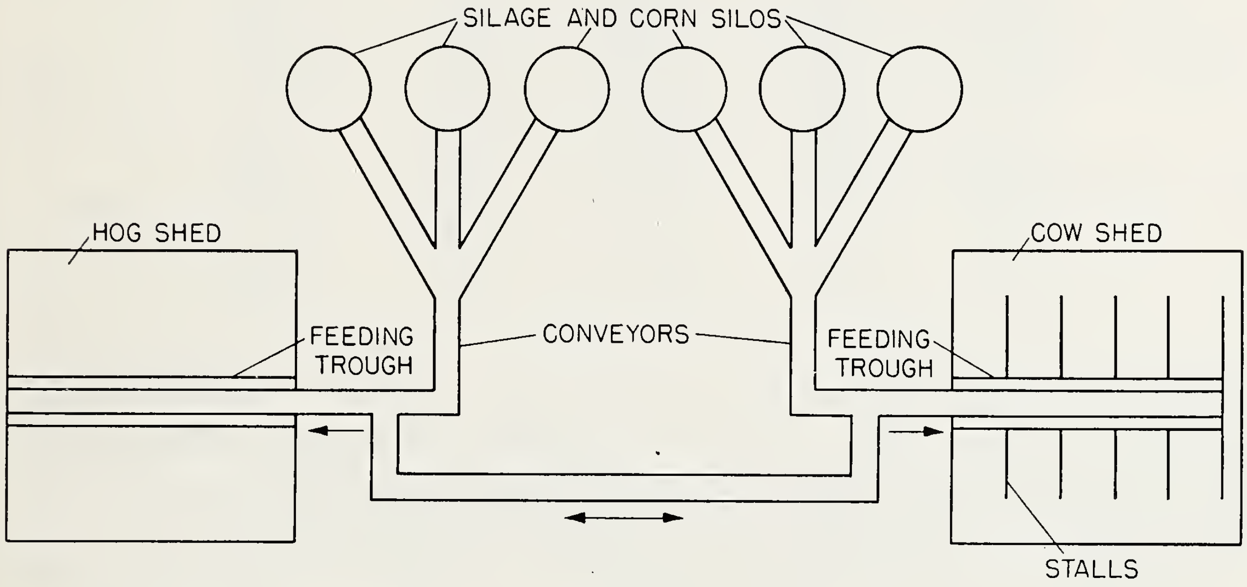
Cattle fattening in the Midwest was not new, but ordinarily it was cheaper to pay the transport costs for the animals from Oklahoma, Texas, and other states to Chicago rather than raise cattle in the Midwest. With Fred Johnes, Inc. methods, however, the cost of production was cut so substantially that production became cheaper a few miles from Chicago than getting the livestock from the West. The first year netted 15% on the bank's investment. Mr. Fred Johnes, in turn, repurchased several blocks of stock from the bank at the option price of $25.

Although 12 years later the bank still held approximately 25% of the outstanding stock of Fred Johnes, Inc., operator-manager Fred Johnes did not hurry with repurchase of the shares still outstanding. The bank and Fred were now partners in a very profitable venture. The bank furnished working capital and Fred in turn raised, fed, and auctioned off cattle in Chicago and assumed plant management, including purchasing of feeds, minerals, chemicals, and pharmaceuticals. His plant turned out approximately 10,000 cattle per year with three employees, excluding Fred and his family. The rest was done by automatic feeding equipment consisting of a number of giant silos and pipelines connecting silos with feeding and living quarters. In a pipe passing in front of the silos, snake-like augers mix and propel the feed through conduits passing directly over 800 feet of dual-sided feed troughs. Opened at predetermined time intervals, trap doors drop feed into the troughs. Water is carried to the stations in the same manner at predetermined intervals. The control panel is so programmed that everything goes on automatically. When the weather is hot, adjustment in water quantity and frequency as well as in the composition of the feed takes place via a thermostatic control mechanism. The programming is done by Mr. Fred Johnes. The responsibility for filling up the silos rests with the three employees. Cleaning is done mechanically, via built-in showers and drainage devices. The three employees, however, do a great deal of the work in connection with the cleaning process.

On the basis of the tremendous success of the beef meat business, Mr. Fred Johnes proposed to the banker stockholders an expansion of operations into the "pork meat business." He suggested an additional investment of $45,000 in silos and some new buildings as well as lengthening pipes and conduits already in use. Old housing facilities, to be interconnected with additional facilities, would enable the plant to fatten 1000 swine. Since hog sheds would be adjacent to cattle feeding facilities, a $100,000 to $150,000 investment could be acquired for only about $45,000. The expansion would not overburden the three employees or the automatic feeding system.

Mr. Johnes claims that the proposed addition to already existing facilities would permit raising 500 Hampshires and an equal number of Herefords, selling at excellent prices most of the time. According to careful calculations, he expressed the belief that a 25% return on investment is no exaggeration. "I have already demonstrated to you," stated Mr. Johnes, "that the assembly line technique of industry is applicable to meat fabrication; and in an integrated plant where both swine and cattle are raised, profitability would be more stable than in a one-brand livestock plant." Because livestock were to be kept indoors, the animals would never be exposed to weather conditions. Furthermore, better quality could be attained in view of the fact that "the hogs would not search for food, but feed would instead move to them, and an extra 17% would be added to net weight—mind you without any extra expense—within the same maturing period of time."

The proposed arrangement (showing only one side of the view arrangement) of plant facilities as designed by Mr. Fred Johnes is indicated in the accompanying illustration. According to newest ideas, hog and cattle sheds, indicated on the diagram, would be connected with pipes and conduits to the silos. Feed would be mixed and transported from the silos by conveyors in the conduits to both cattle and pigs which would eat and sleep at the same place. The assumption is that this way a better utilization of plant facilities makes a faster fattening of animals possible.



To support his argument in favor of introducing hog production, Mr. Johnes prepared the data given in the accompanying table. The table starts with production and consumption data as of 1945 when he experienced financial setbacks. From this table it is apparent that the supply and demand conditions changed so drastically in that year that a loss was inevitable. The cessation of hostilities in Europe and Asia cut off the tremendous need of the armed services. But had he been producing with the present methods of production, even then profit would have been realized.

The pork meat market is not as dynamic as the beef market; nevertheless, it is stable enough to help keep profitability at high level. This would be an advantage. Furthermore, the overhead cost could be shared by both the cattle and the swine business. Assuming a swine turnover of three times a year, the overhead cost could be about $1.50 per hog. If hogs could be turned over twice (2000 hogs per year), the overhead would be about $2.25 per hog and the production of only 1000 hogs would cost $4.50 per hog. (The calculation is based on the 10-year straight-line depreciation method.) Prac-

PRODUCTION AND CONSUMPTION OF BEEF AND PORK
(In Millions of Pounds)

YEAR	BEEF		PORK	
	Production	Consumption	Production	Consumption
1945	10,276	7,665	10,697	8,598
1947	10,432	9,163	10,502	9,919
1948	9,075	9,439	10,055	9,840
1949	9,439	9,529	10,286	9,991
1950	9,534	8,472	10,714	10,390
1951	8,837	9,548	11,481	10,857
1952	9,650	12,113	11,527	11,112
1953	12,407	9,916	10,006	9,900
1954	12,963	12,737	9,870	9,549
1955	13,569	13,306	10,991	10,834
1956	14,462	14,121	11,221	11,147
1957	14,777	14,777	10,234	9,342

tically no one can produce hogs at such a cost, assuming that feed and feed subsidies cost pretty much the same throughout the country. Of course, the important point in the Johnes case is that a substantial part of current facilities can be made accessible for the swine-feeding purposes also.

Although the bank group recognized the validity of Mr. Fred Johnes' argument, some misgivings were voiced as to whether it is worthwhile to enter the pork meat business at the time. No one doubts, of course, the soundness of Mr. Fred Johnes' judgment. Based on the facts indicated by the table, his earlier financial difficulties were a result not of poor managerial decisions, but of certain future handicaps that could not easily be foreseen. Production decisions in the livestock business are made ahead of time; by the time the sale is made, almost a year has passed. In the case of the hog business, the situation is not as difficult, because hogs can be turned over three times a year. This of course would facilitate the decisions and would reduce the risk. The profit on investment would be enormous. It appears likely that the cost of production per hog would be approximately 25% lower than that of other producers. Thus, regardless of the market price, profits are more or less assured. It does not seem likely that pork meat price would fluctuate more than $1 or $2 dollars at most per 100 lbs in the 250-pound class. In the 300-pound category, price fluctuation would be even less.

Questions. The case illustrates a different type of production industry than has been discussed hitherto. Nevertheless, the student should be reminded that regardless of what is being produced, raw materials, manpower, and machinery are always involved. When we automate, manual work and a great deal of the administrative work are done by the automatic mechanical and electronic system. Since the market price in the meat business is independent of the production costs, as long as the costs of production can be kept at competitive levels the chances are that the business can break even. For the purposes of calculation, the student should assume a probable price level of $18 to $20 per 100 lbs. Since the weight classification of Herefords and Hampshires would be 250 to 300 pounds, the cost must be compared with possible revenues. To gain proper price and revenue data, consult your daily price quotations in the livestock market. (See the financial pages of your local newspaper.)

1. Assume that you are one of the bank representatives. Since the bank's money cannot ordinarily be invested in risk ventures, your task is to determine whether or not an additional investment is warranted.

To determine this, set up a break-even chart for hog production in order to estimate the yearly hog output versus revenue which would warrant such an expenditure. The overhead cost is given in the case. The material cost such as feed, hormones, and antibiotics would amount per pig to $20 to $30, depending on attained weight classification (that is, weight attained). Revenue should therefore be based on the price given above or on the respective daily price quotation in the daily paper.

Figure out the possible revenues and costs with a turnover rate of 1000, 2000, and 3000 pigs per year. Indicate your decision and support it with a break-even chart.

2. What is your opinion about automation and computer control in the agricultural industry and, in particular, at the Fred Johnes establishment.
3. Make a comparison between automation in the oil refinery business, in the steel-rolling industry, and in the cattle and hog fattening business.
4. Explain the differences between production and conversion decisions in agriculture, particularly in cattle, and hog fattening, and other industries.
5. To what extent would you recommend automation throughout the meat (cattle and hog fattening) business?
6. Had you been a banker, would you have used this roundabout method of getting your money back, or should banks, generally speaking, not lend money for the purpose of automation?
7. What are the risks, if any, involved in the kind of automation in which Mr. Fred Johnes is involved?

chapter 15

Mathematical Methods for Solving Old Production Problems[1]

OPERATIONS RESEARCH

The fact that business of today, mainly because of increased competition, high taxes, and low depreciation allowance, is less profitable than it used to be brought about the employment of operations research to exercise a better control over costs.[2] Apparently, the generally smaller profit margins made the reserve, which used to absorb management errors, correspondingly smaller. Primarily for the above reasons, the need for a more complete and detailed evaluation of cost factors is greater than ever. The new operations research methods make it possible to preaudit the possible impact of pending actions on costs and profitability.

In the connotation used in this text, operations research is considered as a planning tool. It should, however, be recalled from the preceding chapter that operations research can also be an integral part of the automatic control system. In both instances, however, operations research is used in the solution of complicated production problems. As a planning tool, it replaced in a few selected companies the simpler graphing and charting methods of planning with a more rigorous and formalized mathematical approach.

Operations research can be defined as a mathematical approach to planning applicable to many fields of industrial endeavor, including production. In this new approach, the planner no longer relies on the highly subjective seasoned judgment, but instead relies primarily on the cold logic of mathematics, including statistics.

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[1] Appendices B, E, F, and G deal with quantitative concepts in general, and matrices and linear programming in particular.

[2] In the 1950s the total of all corporate profits (after taxes) remained at the level of the previous decade despite the fact that the GNP—the aggregate value of goods and services—increased by nearly 75%.

To illustrate the possible use of operations research methods in the field of production planning, recourse must be made to the fact that the planner—whether in intermittent, repetitive, or continuous production situations—must make choices from several alternative manufacturing methods, inventory practices, and scheduling possibilities. There is always a *one best way,* but it is not easy to ascertain which way is the best one. This is where operations research can be of great help.

In job shops, the routing-scheduling problem lends itself to operations research applications. The planner must select from the various alternative possibilities the one which will cause the least cost but which does not violate any other requirements (sequence, delivery commitment, and technical feasibility). In repetitive operations, the costwise best product mix, in light of inventory position, can be ascertained with operations research methods. In the continuous production method, bottleneck stations resulting from faulty inflow of raw materials can be eliminated with the help of a study of arrival rates; operations research will permit the determination of the minimum amount of inventory levels which still permits a continuous flow of production without taking undue chance of running out of raw materials; operations research will also help in the determination of manufacturing policy—when to shut down or operate, stock up or deplete inventories, etc. to attain the minimum of operating costs.

Although profitability depends on the excellence of the production plan, it is difficult to arrive at a perfect plan of action. There are so many ramifications to every production problem that it is easy to overlook an important factor. Consequently, it is nearly impossible to operate industrial enterprises without making errors. The error might result from poor judgment or from an accidental disregard of an important factor, a factor which might seriously affect the outcome of a plan. The factors which surround every production problem are so numerous that an oversight is quite possible. Nevertheless, unless all relevant factors—tangible or intangible, static or variable, known or unknown—are taken fully into consideration and brought to a common denominator, the plan might not fully attain company objectives.

Scientific management is an improvement over the methods of management when management tools—budgets, scale models, graphs, charts, and time studies—were not used to develop production plans. Although these management tools helped to make decisions scientific, operations research methods are claimed to improve even over the scientific management methods.

To what extent operations research improves over the conventional management methods (scientific management or otherwise) is hard to say, but the fact is that the fallible judgment factor is replaced with statistics and the more reliable mathematics is used to weigh the merits of alternatives.

To fully understand either the similarities or the differences between the conventional method—basing managerial decisions on common sense rather than on scientifically ascertained facts—and the operations research method, one must be aware of the requirements which operations research techniques presuppose. Thus, for instance, in order to practice operations research, data must be available. And the information which is required to carry out the various mathematical computations is not easily come by. Furthermore, it is essential to update the information all the time, because any change in one of the data used in the computation might throw off the whole calculation.

Basically, in the operations research method, mathematics is used to compare relevant factors with one another and statistical methods are used to assess the probable value of unknown factors which must be made available in numerical form in order to use them in the mathematical calculations. Whereas in the conventional decision-making method unknown factors are ascertained by taking a guess on a possible outcome (by making certain assumptions), in the operations research approach the unknown factors assume —via the statistical probability theory—numerical values. The use of numerical values is important, because every other element which might be influenced by this probable value will be treated uniformly. With the guesswork method, whereby factors are merely approximated and manipulated in one's head, the weight given and the value assigned to a chance factor tend to vary and lead to different results. Of course, the use of statistics is not foolproof either. The best mathematical computation might lead to the wrong conclusion if the operations researcher made the wrong assumption—based, for instance, on a fallacious statistical inference.

Generally speaking, operations research techniques do not treat any phenomenon as if it were isolated, but handle each problem, however small, as a composite of a series of other interrelated problems. In the conventional method, the planner tends to select a few important factors (because he cannot manipulate hundreds of factors in his mind), and those which have a "negligible amount of influence" he disregards. However, some insignificant-appearing factors may, in the aggregate, be so powerful as to turn profits into losses. To avoid such errors, operations research treats every problem as a combination of things in total. Accordingly, in operations research each and every factor is taken into consideration, but each will carry a weight proportionate to its importance as far as the problem at hand is concerned.

DIFFICULTY WITH THE NEW APPROACH

Although the operations research method is an appealing one, the tremendous amount of information needed and the sophisticated mathematics used in the solution of the problems make it often unfeasible in production planning work. Moore says in effect: Don't be oversold on operations research . . . [because] it has proved to be useful in only the most limited way and only in very specific circumstances. Operations research men figure out hypothetical examples which cover certain circumstances but often can't find any situations that fit the circumstances laid down."[3] Furthermore, in the production situation the "timing" of the action might be important and there is often no time to make an elaborate calculation prior to giving a command. Speed in decision making might be the essence of the situation.

The preceding paragraph infers that the data must be arranged according to the rules of mathematics. That a great deal of ingenuity and resourcefulness are needed in order to adapt available mathematical techniques to specific uses goes without saying. Whereas operations research in automation (particularly in chemical process controls) is quite feasible because the process and the adjustment of the pressure, heat, and flow controls do conform to the rules prevalent in natural sciences, production situations in a machine shop, for instance, cannot be reduced to neat mathematical forms. A chemical reaction is deducible from theory or from empirical observations, but the production problem follows less regular patterns.

Primarily, mathematical competence stands in the way of the universal applicability of operations research techniques. Although to a trained engineer or even to the average college student the mathematics to be used should not appear to be new or even considered earthshakingly difficult, the applicability of known mathematical techniques to the solution of different production problems requires specialized training in operations research methods. To facilitate the mechanics of computation, we have computers all right, but in order to design application possibilities, a better than average mathematical skill is an important prerequisite.

NATURE OF OPERATIONS RESEARCH

It should be noted that operations research is the collective name given to various mathematical approaches to problem solving. When speaking of operations research, we must always think of given problems and given methods which can solve specific types of problems. A comprehensive study of operations research would always be a case study, because every production problem must be treated or handled on its own merit.

One basic reason for some degree of universality of certain mathematical applications lies in the similarity of problems which business units face. Although every plant might think of itself as different, in reality all plants face similar or even identical problems. Only the magnitude of the influencing factors and the dollar volume of business might differ.

Data

Since operations research is a collective name, the methods which have so far been developed for the solution of given types of problems make up the field of operations research. In a sense any mathematical formula which is capable of reproducing a given "real life" situation can be classified under the term. The currently available techniques are, however, applicable only if the circumstances match those represented by the mathematical formula. While there is no limitation as to the method or technique to be used to solve a given production or other business problem, the model must be capable of reproducing the production function and able to show the pattern within which the problem develops and the error of logic which causes the undesirable "result" or "situation" at hand.

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[3] Franklin G. Moore, *Production Control* (New York: McGraw-Hill Book Company, Inc., 1959.)

Earlier it was stated that operations research is based on the application of mathematics and statistics. To clarify things, it should be noted that statistics is not essential to carry on operations research work. If, however, data are not readily available, yet are needed to carry out certain mathematical computations, they must be derived via statistical deductions based on fragmentary observation or probability factors. Thus, in operations research work the function of statistics is to furnish (to "fabricate," so to speak) data —that is, assumptions—which are necessary to the computational pattern. Reference is made here to the queuing theory, probability theory, game theory, Monte Carlo method, random process, etc., which are able in certain situations to furnish data to compute the problem which is involved and is represented by the mathematical formula.

MATHEMATICS AND FORMULAS

Operations research work is a natural extension of scientific management, and the mathematics involved makes it more so. But one must become familiar with the language of mathematics to understand how it works. Although "parameters," "conceptual deviations," "quantitative analysis," and "models," are concepts known to most of us, we know them in everyday language as "influencing factors," "numerical difference," "determine how many," and "formulas," respectively. Once the hurdle of a "doctor's language" unnecessarily mysterious to businessmen is overcome, the nature of the various mathematical and statistical methods must be understood. What can they do and how can they do it?

From among the many operations research techniques available, linear programming is the most common technique applied to problems in the field of production planning and control. This method is based on matrix algebra. Matrix algebra, in turn, relies on linear equations—equations representing proportional relationships between two or more factors. When the data obtained through solving the equations are arranged in a table (matrix) giving a bird's-eye view of the various alternatives, the decision (that is, the plan) can easily be made. Besides this method, quadratic and differential equations and occasionally calculus or other somewhat more sophisticated mathematical techniques, can also be applied.

Since in linear programming interacting factors are compared with one another, it is essential that these factors are linearly (proportionately) related to one another in the sense that with the move of a factor, another relevant (and related) factor will also move proportionately in the same direction. A case in point is the scheduling of more hours of work to obtain a proportionately greater output. If there is a lack of linearity, however, linear programming is not applicable and recourse to other operations research (that is, mathematical) techniques must be had.

PREREQUISITES

The mathematical approach evidently deviates from the informal decision-making method in respect to quantification. Whereas, in the conventional decisional process also, certain weight is given to the different factors taken into consideration, one never makes precise mathematical assessments about these factors. In operations research, however, the precise assessment is necessary. Influencing factors must be changed into symbols to which numerical values must subsequently be assigned. Without quantifying the factors relevant to the problem, operations research cannot be practiced. In this respect, the difficulty is that certain factors cannot very well be quantified. Nevertheless, in operations research it is essential to quantify symbolic data to arrive at numerical end results. Consequently, even intangible factors must be changed into numerical values. The various probability theories mentioned earlier can be useful in this respect primarily because they are able to furnish such numerical values. Hence, probability values enable operations researchers to predict the outcome of certain decisions. To learn about the value of such a factor afterward would not do any good. On the other hand, *forecasting* the value of the unknown factor can be invaluable in the mathematical decision-making processes.

According to an example,[4] even the value of an "intangible" factor can be appraised with the following model:

$$\mathrm{TC} = C_1(x) + \text{other pertinent costs}$$

where TC represents the minimum total costs, and C_1 represents the number of dollars lost corresponding to the loss of x (number) customers. The "other pertinent costs" are independent of the number of customers lost (for example, the fixed costs might be divided among fewer output units). If by not meeting a delivery commitment customer goodwill is lost, it is essential to measure the amount of goodwill remaining. If by abstaining from overtime work (and pay), x number of dollars is saved but concurrently customers refuse to patronize the firm, thus incurring a total loss of $2x$ dollars, it might not be worthwhile to gamble on losing customer goodwill.

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[4] Adapted from Churchman, Ackoff, and Arnoff, *Introduction to Operations Research,* (New York: John Wiley & Sons, Inc., 1957.), p. 115.

Despite the intangible value of C_1 (cost), the minimum of TC (total costs) with respect to x can be found by taking the derivative of TC with respect to x and by making $d\,(\mathrm{TC})/dx = 0$. The solution to the equation, x^*, then determines the minimum of TC which is precisely the value $C_1\,(x^*)$ plus other pertinent costs. By this means we have succeeded in measuring the value of an intangible factor, namely, the minimum total cost TC.

Second to the problem of quantification is the skill of formulating production goals so that a mathematical solution is possible. Thus, before setting up a mathematical model, the objective must also be known in terms of "least cost," "optimum output," "maximum profit," etc. The formula must then reflect the ultimate purpose of computations. Furthermore, the table used to summarize the various alternative possibilities must be so constructed that it clearly indicates the most desirable course of action.

A further requirement is to express in quantitative terms the various limiting factors and circumstances capable of preventing application of the best method, for example, capacity limitations, maximum sales potential, delivery deadlines, time versus capacity limitations, and raw material availability.

Last, but not least, all other influencing factors (parameters) affecting the goals and alternative possibilities must also be expressed in quantitative terms. Whether these are indeed facts or merely statistically fabricated assumptions is unimportant as far as the mathematics is concerned.

THE MODEL

The mathematical formula giving the modus operandi to the solution of given production problems is referred to as the model. It is an abstraction of the real production situation. In a sense, a mathematical model is something like a scale model of a plant layout. One can visualize how things will look in reality.

Models tend to reveal the true nature of the most intricate interrelationships of relevant factors. Expressed in algebraic form, cause and effect can readily be recognized. Subsequently, by simply substituting different numerical values for given symbols which represent various cost parameters or other influencing factors, several alternative plans can be formulated. Of course the plan thus formulated will always depend on the validity of the assumptions the planner made relative to the values of various influencing factors.

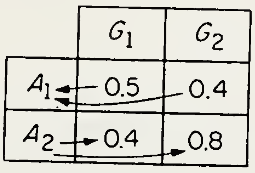
Models help in selecting the best plan from among a number of alternative possibilities. Yet despite the usefulness of the formula, the planner cannot rely on it blindly. Management makes the decision, not the formula. Mathematical models merely help to weigh the alternatives according to scientific principles. Thus, models merely foster objectivity otherwise likely to be obscured by emotional factors.

PLANNING THROUGH OPERATIONS RESEARCH

The nature of planning with operations research can be illustrated by assuming a dual (rather than singular) goal, symbolically expressed as G_1 and G_2. If we assume that there are two methods at the disposal of the planner, namely, A_1 and A_2, and that either one of them can accomplish both goals, the following reasoning can be developed. Both A_1 and A_2 have a certain comparative advantage in achieving one of the two goals. Let us say A_1 can achieve G_1 better than G_2; similarly, A_2 is more suitable to the attainment of G_2. But such vague assessment is inadequate to determine which alternative would accomplish both goals so that overall results were optimized. Therefore, one must know which goal is more important as far as the company is concerned and which of the two alternatives can attain either G_1 or G_2 with a greater degree of efficiency. Thus, these factors also must be expressed in numerical terms.

If G_1 refers to *adherence to delivery commitments* and G_2 to *low-cost operations,* it is necessary to decide whether a shipment should be made even at the cost of overtime pay or whether cost is so important that nothing justifies such a decision. By not meeting deliveries, customer goodwill might be lost; in turn, overtime work might wipe out profits.

By using a competitor's efficiency as a yardstick, let us assume that the efficiency of A_1 and A_2 are (relative to G_1 and G_2) as indicated in Fig. 15-1, where 0.5 indicates 50% efficiency and 0.8 indicates 80% efficiency.



	G_1	G_2
A_1	0.5	0.4
A_2	0.4	0.8

FIG. 15-1

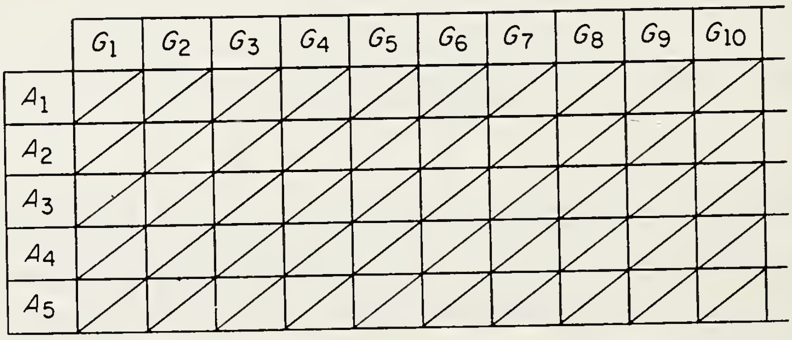
If strict adherence to delivery commitment is considered important, the first alternative, that is, A_1, must by all means be chosen; if, however, meeting delivery commitments is subordinated to the cost considerations, A_2 must be chosen. If both are of equal importance, then A_2 is chosen. Assuming, however, that neither consideration should exclude the other, the relationship between G_1 and G_2 must then be expressed in relative terms. In other words, an *importance factor* must be established which would represent the true importance of any one of these two goals from the overall company point of view.

Although the importance factor also can be scientifically determined, for the purpose of this illustration only an arbitrary value is assumed. Accordingly, the first goal is less important to the company and carries a weight of 0.2, whereas costs have a weight of 0.5. The calculation is as follows:

Goal	G_1	G_2	*Total*
A_1	$0.2 \times 0.5 = 0.10$	$0.5 \times 0.4 = 0.20$	0.30
A_2	$0.2 \times 0.4 = 0.08$	$0.5 \times 0.8 = 0.40$	0.48

A_2 would, accordingly, accomplish overall company goals better than alternative method 1. This, of course, by no means implies that the company disregards the importance of delivery commitments; it implies only that the company places greater weight on breaking even than on pleasing customers at all cost. Without giving relative weight to factors, the planner would not always be consistent in his decisions; with the mathematical approach, however, consistency can be fostered.

As more goals are expressed in terms of a common denominator, the greater the number of alternative methods that must be considered and, subsequently, the more difficult the task of the planner becomes. By the same token, this procedure tends to become more complex. Without going through a large number of computations, let us outline a plan whereby ten goals are set and five alternative methods are available. Of course, each alternative can accomplish each of the ten goals with different degrees of efficiency. Thus, the problem can be shown in a table in which the horizontal line indicates the ten goals and the vertical line the alternatives. By splitting each box into two halves, one can contrast the relative importance of various goals to one another and the ability of each alternative to accomplish any specific goal (as expressed in an efficiency index). Thus, the plan would look something like Fig. 15-2.



	G_1	G_2	G_3	G_4	G_5	G_6	G_7	G_8	G_9	G_{10}
A_1										
A_2										
A_3										
A_4										
A_5										

FIG. 15-2

OPERATIONS RESEARCH AND UNKNOWN FACTORS

Unknown factors are important handicaps to decision making. The actions of competitors—always unknown factors—will definitely influence any business decision. Although most competitors keep their plans secret—whether in the sales, production, financial, or other areas—some fragmentary information might leak out. On the basis of such information, another company can make reasonably correct conclusions with respect to its own plans.

A case in point is selected to illustrate more vividly the concept discussed in the preceding paragraph. Company C is sharing a given market with two other firms. These three firms, referred to as companies A, B, and C, turn out 95% of total output; the residual 5%, made by smaller firms, is considered negligible. Subsequently, if we assume that the total industry sales are known, along with one's own sales figures and possibly the knowledge that B sold 10 million tons more than A, it is possible to determine without any difficulty the appropriate share of the market of each of C's competitors, namely, A and B. If industry sales (sales by A, B, and C) amount to 50 million tons and C's own sales amount to 10 million tons, the total combined sales of competitors A and B are evidently 40 million tons. To determine the unknown quantity of competitors A and B, the equations

$$x+y=40 \qquad \text{and} \qquad y=x+10$$

must be set up. The fact that x represents the unknown output of competitor A and y that of competitor B is, from the point of view of mathematics, unimportant. The task merely is to find the answer to the above two equations. When the computations are taken care of, the answer must be suitably interpreted.

By replacing y in the second equation, $y=x+10$ (that is, the sales volume of competitor A), the value of x can be computed in the following manner:

$$\begin{aligned} x+(x+10) &= 40 \\ 2x+10 &= 40 \\ 2x &= 40-10 \\ 2x &= 30 \\ x &= 30/2 \\ x &= 15 \end{aligned}$$

Because competitor B is known to have sold 10 million tons more than competitor A, the conclusion is that

$$y=15+10=25$$

In the sales-forecasting procedure, it is conceivable to make computations of this kind to ascertain competitors' share of the market. Accordingly, A sold 15 million tons (30%), B sold 25 million tons (50%), and C sold 10 million tons, equivalent to a 20% share of the market.

OPERATIONS RESEARCH AND UNCERTAIN FACTORS

Uncertain factors are known in *tolerances* only. The sales of another competitor are between 20 and 25 tons. It is uncertain whether they are 21 or 22 tons, and it is conceivable that they are 23 or 24 tons. At any rate they are not less than 20 tons nor more than 25 tons.

Since some factors which must be taken into consideration are only vaguely known, these "semiknown" factors must be handled in operations research work in the same manner as the unknown factors. Thus, the company in question might know that 3 million tons is its break-even point, 10 million tons is its maximum, and 7 million tons is its optimum output. At optimum level, the plant operates at the lowest unit cost; beyond that, cost rises faster than revenues. Although the sales quantity is unknown, those factors already known may be expressed in inequalities and as a basis for solution. Accordingly, output should be greater than 3 million tons, but not more than 7 million tons. Putting it in another way: 3 tons is less than the output, and the output is less than 7 tons. Algebraically,

$$3 < \text{output} < 7 \qquad \text{or simply} \qquad 3 < 7$$

where $<$ is read "is less than." For example, if one identifies the algebraic symbol x with the desired plant output, then the fact that the optimum output is less than the plant capacity of 10 million tons may also be expressed as $x < 10$. If cost is secondary (as, for example, in cost-plus contract), a statement "output should be equal to but not greater than 10 million tons" may be warranted. Algebraically, this is written as $x \leqq 10$).

Since it would be difficult to deal with inequalities, the inequalities should be transformed into *equations in one unknown.* If this maneuver is accomplished, the unknown factor can be found in a manner similar to that already indicated (see the preceding sales-forecasting example). How can an inquality be turned into an equation in one or two unknowns? It is easy! The "uncertainty" in $x < 10$ is replaced with another unknown as follows:

$$x + y = 10 \qquad \text{or with two unknowns} \qquad x + y + z = 10$$

where the additional unknown is the amount by which the left member of the inequality is less than the right member. In light of the fact that equations with one unknown factor are stated, in general terms, as $ax + b = c$, the above equation would possibly be stated as $ax + b = 10$, where x is the unknown factor and a and b are the values which do not equal zero. However, this always depends on the computation's assumption.

This has been explained primarily because inequalities and linear equations constitute the core of operations research work applied in the field of production (called linear programming). In linear programming, y and z above might be called "slack variables having the purpose of absorbing idle time" (see p. 710).

The mechanics applied to the solution of linear equations follows a pattern. Hence, if b is subtracted from both sides of the equation of $ax + b = c$ and both sides are divided by a, the solution is $x = (c - b)/a$. By knowing this rule, an immediate transformation of x can be made and placed into the equation as restated

$$a\,\frac{c-b}{a} + b = c$$

(based on the original $ax+b=c$), where $(c-b)/a$ represents the value of x.

It should be noted that other equations with two, three, or more unknown factors can be solved in the same manner. Once the unknown factor assumes a *value,* the next unknown factor can be solved on the basis of the answer to the preceding equation. This is called *iteration.*

QUANTIFICATION AND SYMBOLIZATION

In operations research work, models depict production situations in algebraic form. These can employ numbers, symbols, or any other means of identification. Whether these symbols are letters of the Roman, Arabic, or Greek alphabet is irrelevant. Care must, however, be taken with numbers because a number cannot be manipulated in the same manner as a symbol. With numbers we can express only homogeneous items, but with symbols we can even express mixtures without any misunderstanding. While $1+2=3$, this is so only if we add, for instance, 1 apple and 2 apples; 2 bottles of vermouth and 1 bottle of gin are no longer $2+1=3$ because what we get is neither vermouth nor gin. To avoid difficulty of a similar kind, it is better to use symbols. If vermouth is represented by the letter A and gin by the letter B, one bottle of A+one bottle of B would be C; $A+B=C$ (martini). The letters x, y, z are usually employed in equations to depict the *unknown* factors.

THE PROBABILITY THEORY AND UNKNOWN FACTORS

In the linear equation $ax+by+c=0$, x and y are the two unknown factors. Letters a and b are the multipliers (coefficients), whereas c is the constant factor. The values of x and y are then multiplied by a and b, respectively.

By substituting in place of an unknown an *arbitrary* value, an equation in two unknowns can be reduced to an equation in one unknown. This in turn can easily be solved on the basis of the new known factor. This arbitrary value does not have to be a figure taken out of thin air. As a matter of fact, in operations research work this arbitrary value is often taken from statistically valid experiences. Thus, the unknown factor is ascertained on the basis of the probability theory and is used toward the solution of the problem. Obviously, then, the value is arbitrary only in a sense that we are not sure that it is exactly the value which will be found in practice. But according to the probability theory the arbitrary value has the best chance to be valid. An equation in two unknowns, then, *will have an infinite number of solutions.* Depending on what value we work with, the answer will be different. Thus, in operations research work, the various probability theories are enlisted to find such arbitrary values (via either Monte Carlo method or random processes, queuing theory, or game theory) which subsequently will be used in the equations.

Since each arbitrary value or statistical datum (when it replaces an unknown factor in the equation), yields an appropriate answer, the value 1 assumed to represent y in an equation (such as $2x-3y=5$) will show that x is equal to 4. Let us see how this is arrived at:

$$\begin{aligned} 2x-3&=5\\ 2x&=5+3\\ x&=8/2\\ x&=4 \end{aligned}$$

In conjunction with equations and linear programming (linear equations applied in operations research work), mention was earlier made of a matrix. The matrix is used to arrange the various answers gained from the various assumptions (based on arbitrary numbers selected to replace unknown factors). The matrix permits a careful study of the various alternative possibilities and helps in the decision-making process.

A more complicated production problem might have to take recourse to such a model. It can be carried out in a patternlike fashion. Generally speaking, the process of solving two simultaneous linear equations with two unknown factors resembles the solution of a linear equation with two unknowns. To exemplify, let us assume that

$$\begin{aligned} 3x-2y&=8 && (1)\\ 2x+5y&=-1 && (2) \end{aligned}$$

By taking 2 as the multiplier of equation 1 and 3 as the multiplier of equation 2,[5]

$$\begin{array}{lrl} 3x-2y=8 & 6x-4y=16 & \text{multiplying by 2}\\ 2x+5y=-1 & \underline{6x+15y=-3} & \text{multiplying by 3}\\ & -19y=19 & \text{subtracting}\\ & y=-1 & \end{array}$$

Now, the solution to x will result from substituting -1 for y in either of the above equations. Thus,

$$\begin{array}{lll} 3x-2y=8 & 3x-2(-1)=8 & \text{letting } y=-1\\ 2x+5y=-1 & 2x+5(-1)=-1 & \text{letting } y=-1 \end{array}$$

Ultimately, then $x=2$.

From the point of view of mathematics, the number of unknowns is unimportant, except that at least as many, but preferably more, equations are needed than there are unknowns. This is so because it is possible to get rid of all unknowns through an elimination process. This eliminative process uses the same mathematical scheme in that the solution to the first equation (the first unknown which becomes known) is used to solve the unknown factor in the next equation. Depending on the number of unknown factors that the problem contains, the computation is repeated again and again by using the result of the preceding equation. This technique is referred to as iteration. Iterative techniques of solving systems of simultaneous "inequations" (that is, inequalities set up with unknown factors; see explanation on p. 698) with a view to choosing the optimal alternative from a set of solutions are the subject matter of many operations research problems.[6] Among these iterative techniques the transportation and the simplex techniques are the most important. There are, of course, many other techniques, and each has a place in operations research work. In this writer's opinion, the main thing the student should remember is that some of these techniques have certain applicability in specific production (or other) situations. Thus, the technique is important only in the sense that it has been tested and retested in practice and that experimentation with other techniques can be avoided.

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[5] The objective of finding suitable numbers is that they make the multipliers of x in both equations the same values. They could have been just as well 4 and 6, respectively, or any other suitable numbers.

OPERATIONS RESEARCH IN ACTION

As previously stated, certain problems of intermittent and repetitive or continuous production shops can be solved with certain operations research techniques.

None of the examples will spell out every mathematical step. Nevertheless, the ideas are covered in such a manner that a careful reading will instill a pretty good understanding. The case studies show typical problems in which operations research techniques are applicable. It should be remembered that not every situation can be illustrated. The examples that have been selected follow the general pattern of this book.

It has already been pointed out that operations research, particularly linear programming, is time consuming. Thus, the large number of mathematical computations can, in many situations, make this new approach impractical. It must always be remembered that the savings which operations research can achieve must be considerably greater than the expense of computational work and researcher time. For this reason, unless the mathematics can be done by computers, operations research is often not worth its cost.

It should be noted, however, that in smaller companies, it is often more beneficial to use charts and graphs to solve certain problems which could possibly be solved through operations research because the skill to work out the problems with a precise mathematical technique is not readily available. However, the increasing use of electronic computers contributes to a wider applicability of this new planning technique.

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[6] However, there are several other reasons for the use of iterative techniques. Thus, for instance, the same unknown factor can often be found on both sides of the equation, stated as $x=f(x, y, z)$. The problem then can be resolved by estimating the value of x, testing the estimate, and, if wrong, making a better estimate repeatedly until an acceptable value is attained. To estimate in such a manner means, then, "to iterate."

JOB SHOP PROBLEMS

Scheduling production of a new order is one of the headaches of job shops. Since each order can be sequenced and scheduled in many different ways, it is difficult to pick the costwise and otherwise best alternative. To accomplish this objective, the planner must wade through a large multiplicity of cost considerations and other production relationships dealing with order priorities, output capabilities (as indicated by time standards), and many other factors relevant to the solution of the problem.

Problem 1.[7] A company engaged in intermittent production has received six orders to be scheduled according to customer delivery specifications. Each order must go through six different operations. Therefore, 36 interrelated problems must be considered. The summary of the six process sheets indicates, see Table 15-1, the order quantity, operation sequences, and the equipment to be used. Although the name and function of the equipment are unimportant, they are given in abbreviated form as follows:

TABLE 15-1

SUMMARY OF SIX PROCESS SHEETS (SIX ORDERS)

Order	Operation Name and Number												Order Quantity
	1	2	3	4	5	6	7	8	9	10	11	12	
A	*d*	*g*	*w*	*r*	*s*	*m*							60
B	*s*	*d*	*g*	*r*	*m*	*d*							20
C	*w*	*r*	*d*	*m*	*d*	*g*							40
D	*r*	*s*	*m*	*d*	*g*	*w*							80
E	*s*	*m*	*d*	*g*	*d*	*g*							100
F	*m*	*d*	*g*	*w*	*r*	*d*							35

m = milling machine
d = drill press
g = grinder
w = welder
r = radial drill
s = sand blaster

Of course, it should be remembered that in job shops the various milling machines, for example, are lodged in the milling department and the drill presses and other departmental equipment are lodged in appropriate sections of the plant. Also, the fact should not be neglected that there are dozens of milling machines, drill presses, grinders, etc. Each milling machine is capable of performing any milling operation, except at differing rate of speed or at lower or higher costs per unit. The book value, and therefore the unit cost, of the equipment used, depends on the acquisition price, age, and method of depreciation applied to the equipment. The setup time (and cost) might at times also be of considerable importance. In this case setup time does not amount to much and hence is considered, for all practical purposes, insignificant. To process an order, recourse must be had to the process sheet indicating the equipment which must perform the various operations and the sequence in which the operation must be completed. For the example being considered here, let us assume that the sequence is not interchangeable.

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[7] Based on Robert O. Ferguson, "Linear Programming," Special Report 389, American Machinist, April 11, 1955, p. 122, dealing in particular with the *index method.*

There are 36 operations involved in processing the six orders, and all of them must be booked. However, only the scheduling of the milling operations will be illustrated. The rest of the operations would be carried out in the same manner as milling. For sake of simplicity, none of the milling operations conflict. In normal practice things do not work out as smoothly. In this example everything has been oversimplified.

If we assume that the milling department has five milling machines equally suitable for performing all these milling operations (on all six orders), the question that arises is to which machine order A, B, C, D, etc. should be assigned. As stated before, each machine, acquired at a different time, has a different book value. Also, the newer machines are more *efficient;* that is, they can perform the same operation faster than other comparable but older machines. Furthermore, each machine lends itself to certain jobs better than to others and can be operated at faster (or slower) speed and feed. These differences are reflected in the standard *operation time.* Table 15-2 summarizes the time study data relative to all milling operations. (All other operations are deleted; otherwise, they would have to be carried out in the same manner as the milling operations). Time study data are given in decimal hours per unit.

TABLE 15-2

TIME STUDY DATA SHEET RELATIVE TO THE VARIOUS MILLERS

Order	Milling Machines				
	I	II	III	IV	V
A	3.0	0.5	1.0	1.5	. . .
B	. . .	. . .	. . .	7.0	4.0
C	2.0	3.0	6.0	4.0	9.0
D	2.0	4.0	3.5	3.0	3.2
E	. . .	6.0	2.0	3.0	4.0
F	. . .	6.0	2.0	3.0	3.0

NOTE: Time study data are given in decimal hours per unit, that is, x amount of time per piece.

Table 15-3 indicates *relative efficiencies* of each milling operation on every order relative to every other order. This is done through an *index* *number*. According to the time study data, A's milling operation can be completed with several alternative possibilities, but of course each alternative possibility results in a different time (and cost) requirement. Hence, milling machine II could mill all workpieces in ½ hour, whereas milling machine I would require 3 hours for the same work, milling machine III one hour, and milling machine IV 1½ hour, etc. to finish the milling operation on order A.

TABLE 15-3

RELATIVE EFFICIENCIES OF ALTERNATIVE ROUTING POSSIBILITIES

Order	Milling Machines				
	I	II	III	IV	V
A	5.0	0	1.0	2.0	. . .
B	. . .	. . .	. . .	0.75	0
C	0	0.5	2.0	1.0	3.5
D	0	1.0	0.75	0.5	0.6
E	. . .	2.0	0	0.5	1.0
F	. . .	2.0	0	0.5	0.5

NOTE: The spaces left blank indicate that the machine is not able to perform the operation in question, that is, the jig may not fit the machine.

Relative efficiencies can be established by assuming that the time of the best machine is the *criterion* of efficiency. Since milling machine II is the best as far as order A is concerned, it would receive the *index number of 0*. Let us deduct 0.5 hour (the time which M_{II} would require) from the other times and then divide all machine times which are capable of performing the operations on A by 0.5 hour to find the respective *index number*. Accordingly,

$$\begin{aligned} M_{\text{I}} &= 2.5 \div 0.5 = 5.0 \\ M_{\text{II}} &= 0 \div 0.5 = 0 \\ M_{\text{III}} &= 0.5 \div 0.5 = 1 \\ M_{\text{IV}} &= 1 \div 0.5 = 2 \end{aligned}$$

The same thing must be done with every order and every alternative possibility. The best alternative is always the criterion of comparison which gives the index number.

Even by a cursory look at the table of *index numbers* it is apparent that the best course of action would be to assign A's milling job of 60 pieces to M_{II}, B's milling operations to M_{V}, C's to M_{I}, D's to M_{I}, E's to M_{III}, and F's order also to M_{III}. But now we enter the scheduling problem—the conflicts with other job assignments to the same machine! Obviously, a machine can do either this or that, not both at the same time.

Let us assume that the machine load chart has the production situation shown in Fig. 15-3. Assuming that all orders must be completed on a given date, the delivery date is one of the restrictions; furthermore, present machine occupancy must be considered. Yet, the optimum result in terms of efficiency must be achieved.

According to good sense, work should be assigned to the most efficient machine and the overflow to the next best machine.

Let us see now how linear programming, and particularly the index procedure, accomplishes the routing-scheduling function. To allocate available machine time among different uses, a *matrix* is set up in which the same information as is indicated in Fig. 15-3 is depicted, except differently. To find out how many hours we need to complete each order, we have to multiply the best operation time by the number of pieces each order contains. If this is in excess of the available idle time on the machine in question, then the same thing must be done on the next best alternative machine. If there is still an overflow, one goes to the third best machine, and so on until the machines have absorbed all the work load.

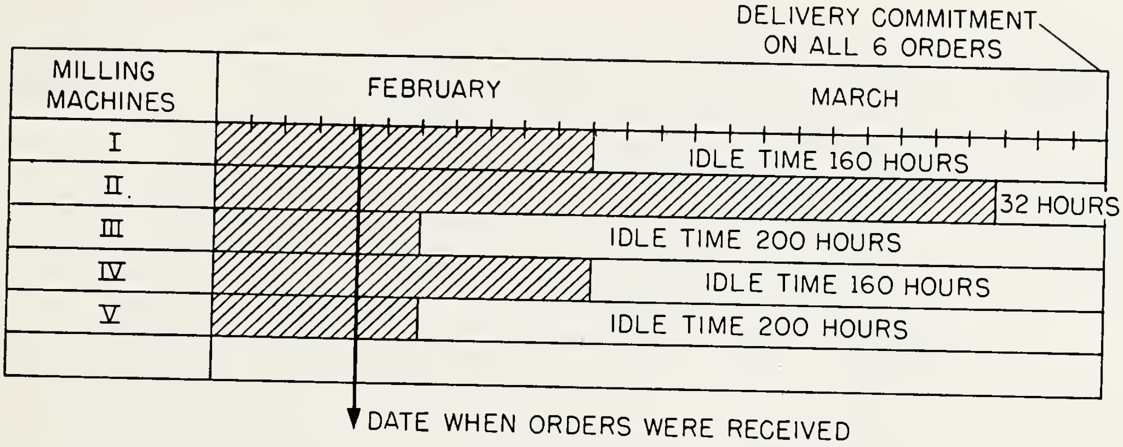


Fig. 15-3. **Machine load chart.**

Of course, if the available machine time is inadequate to complete all the jobs by the end of March, or whatever the deadline is, orders must either be refused or scheduled at a later time—depending on customer delivery needs. This case permits completion of all six orders, and the only question is how work loads should be distributed among the various machines to gain the greatest production efficiency. Figure 15-4 illustrates the appropriate matrix.

The number of pieces to be produced, that is, milled, is indicated in Table 15-1. The following formula helps determine the total time required to complete a given order:

$$\text{Total time} = \text{time required per piece} \times \text{order quantity}$$

Obviously, that particular machine must be selected which requires the least amount of time per piece. If the machine has a sufficient amount of time to complete the order, the assignment is scheduled to that machine. If the machine is already busy with another order, the next best machine must be selected.

As the matrix in Fig. 15-4 indicates, order C should have been assigned to M_{I} and order F to M_{III}, but since there was not enough time on the machine, the order had to be assigned to the next best machine in terms of its efficiency. According to the matrix, 115 more hours were required to carry out the program than would have been necessary under ideal conditions—that is, if there were no restrictions to contend with.

ORDERS		M_{I}	M_{II}	M_{III}	M_{IV}	M_{V}	DEGREE OF INEFFICIENCY*
A		5.0 180	0 30	1.0 60	2.0 90	-- --	
B		--- ---	--- ---	--- ---	0.75 140	0 80	
C		0 ~~80~~	0.5 120	2.0 240	1.0 160	3.5 360	80
D		0 160	1.0 320	0.75 280	0.5 240	0.6 256	
E		--- ---	2.0 600	0 200	0.5 300	1.0 400	
F		--- ---	2.00 210	0 ~~70~~	0.5 105	0.5 105	35
MACHINE HOURS	AVAILABLE	160	32	200	160	190	
	REQUIRED	240	30	270	---	80	

*Expressed in extra hours needed to carry out program.

FIG. 15-4

Figure 15-4 is similar to a map. It shows in each block in the left-hand corner the total time needed to complete the required number of pieces (total time = standard time × quantity), and in the top right-hand corner it shows the efficiency rating of the particular machine as copied from Table 15-3.

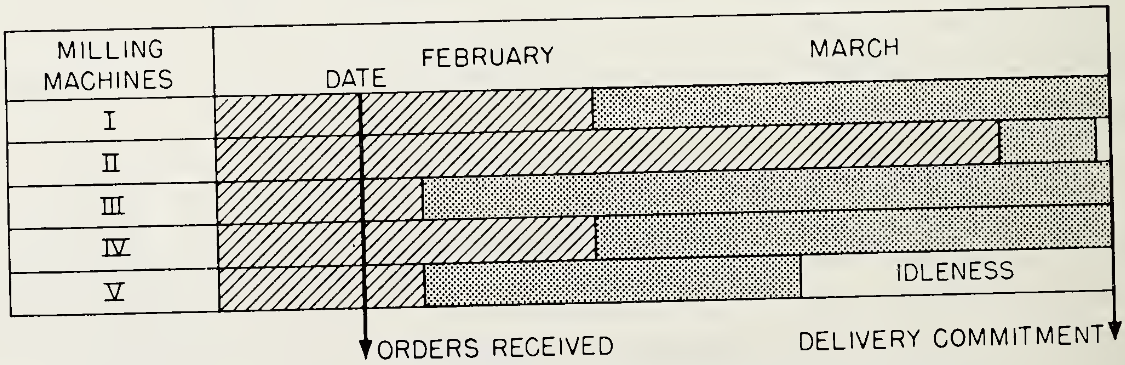


FIG. 15-5. Machine load chart with six new orders added.

Now to illustrate the schedule as it finally has been worked out, the Gantt chart is reproduced, with the added new orders, in Fig. 15-5. According to the schedule, the only two machines still idle are milling machine II and V. The problem could have been more difficult if setup times had to be taken into consideration. But, as was stated at the outset, in this case the magnitude of setup times was considered insignificant. This is not always so, however.

REPETITIVE PRODUCTION PROBLEMS

As is apparent from Chapter 12, repetitive production is a compromise. If for some reason or other continuous production is impossible, recourse is had to repetitive production in view of its greater production efficiency. Generally speaking, in repetitive production, several different items go through the same plant facilities. These items will be produced either alternatively or as sales warrant. Although certain interruptions in the flow of production take place, the plant can still operate in a highly efficient manner.

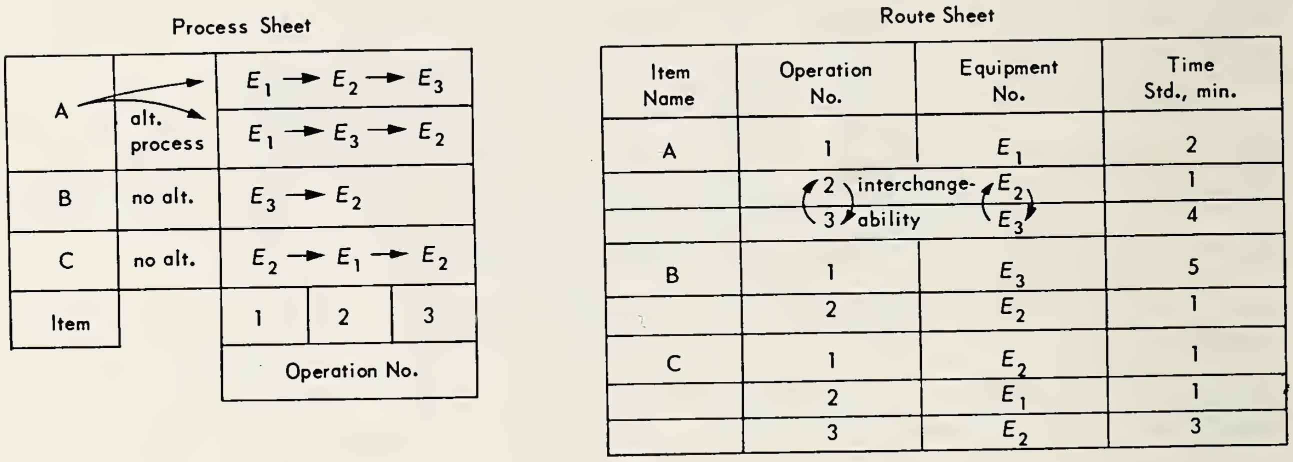
The repetitive producer faces two basic problems such that the decision may be made with the help of operations research techniques: 1) the determination of the economic production run and 2) the costwise best utilization of available facilities (possibly 100% utilization of capacity).

Since the economic production lot calculation has already been given in Chapter 12, pp. 534-535, only facilities utilization will be presented at this time. Where economic lots are produced, the plant uses the same facilities for a multiplicity of purposes. By doing so, an attempt is made to spread the capital cost among different items, that is, more items.

Let us assume that the raison d'être for a product mix lies in the fact that demand is inadequate for continuous utilization of the available equipment. Therefore, the company finds complementary products which can be placed on the same equipment in order to prevent capacity from remaining idle. That between two production runs the machine must be adjusted or converted to the secondary use goes without saying. The cost of setup tends to be lower, however, than the cost of idleness. At this point it must be apparent that the engineering effort to build convertible facilities to several different uses is substantial. But, of course, if capacity utilization through careful scheduling is possible, such effort is well worth its cost.

The main problem in the determination of the product mix is to attain a maximum utilization of equipment. And this is where operations research is useful. The planner has to figure out not only capacity utilization but also the most profitable use. To accomplish this dual purpose, the following example is cited. If demand for all products the equipment is designed to manufacture is excellent, it goes without saying that the company will produce more of the item which sells at higher profit margins than the items with low margin. Thus, if there is a choice, the plant will turn out the maximum of the high-margin item in order to maximize profits rather than the item with a low margin of profit. Here demand conditions will set limitations as to what the company can or cannot do.

Problem 2. Assuming an elastic demand for items A, B, and C, sales can be increased (that is, sales are unlimited) as long as the products are competitively priced. With a quality superior to that of competing products, item A commands 70 cents, item B commands 60 cents, and item C commands 30 cents per unit of output under the assumption of the current efficiency of operations. Since the equipment can be used for either A, B, or C, it stands to reason that as much of each item will be produced as is costwise and profitwise most advisable. Profit maximum is the goal. Out of the three pieces of large-sized equipment (say in a chemical plant), only item A will utilize E_1, E_2, and E_3, as shown in Fig. 15-6.



Process Sheet

Item		Operation No. 1	2	3
A		E_1 →	E_2 →	E_3
	alt. process	E_1 →	E_3 →	E_2
B	no alt.	E_3 →	E_2	
C	no alt.	E_2 →	E_1 →	E_2

Route Sheet

Item Name	Operation No.	Equipment No.	Time Std., min.
A	1	E_1	2
	2 interchange-	E_2	1
	3 ability	E_3	4
B	1	E_3	5
	2	E_2	1
C	1	E_2	1
	2	E_1	1
	3	E_2	3

FIG. 15-6

In order to recover fixed cost, a high degree of capacity utilization is in order. Generally speaking, a step-up in production will permit a better use of facilities and manpower; and, at the same time, the spreading of fixed costs over a greater output level. As already stated, the thus achievable reduction in unit cost helps to relieve the profit squeeze.

To summarize the problem at hand, the available monthly production time (one-shift operation: 20 days × 480 minutes = 9600 minutes) cannot exceed the capacity limit (restriction). 100% capacity utilization means, then, that all the 9600 minutes on every piece of equipment is utilized, or 28,800 minutes on all machines collectively.

Maximum capacity utilization is the ideal, often unachieveable, toward which one strives. An attempt must be made to apportion production time on E_1, E_2, and E_3 among the various units of A, B, and C items so that the maximum capacity is utilized and, at the same time, the profit is also maximized. In order to minimize setup costs, the economic lot quantity may not be broken up, in the sense that the company makes only one setup per operation. When all units at any given operation are completed, the lot as a whole is transported to the next machine. In the case of overlap scheduling, a part of the lot may be transported as soon as numbers of units adequate to allow start of the next operation are completed.

Keeping the above two limitations in mind, namely, available capacity on each machine and economic lot quantity production (that is, no less than economic lot production) with one setup, two mathematical approaches may be applied:

APPROACH 1. If T_j designates capacity, expressed in time, of a machine, and R_{ja} is that portion of capacity which remains after x number of units of item A are turned out, then R_{ja} will be found by the formula

$$R_{ja} = T_j - a_j x$$

where a_j refers to utilization of machine j, in minutes, for the purpose of producing x number of item A. Evidently, processing $a_1 + a_2 + a_3 \leqq 9600$. Based on a limitation mentioned above, $T_j = 9600$ minutes. To reiterate:

T_j = total available time capacity of a machine
a_j = utilization of machine j (on item A)
R_{ja} = remnant of machine time after x number of unit of A and subsequent units are produced

The number of B (or, later, C) items that E_j can accommodate in R_{ja} time is R_{ja}/b_j. In the formulas so far given, a_j and b_j represent operation time on a given machine relative to item A or B. Since item A must go through three consecutive operations, there are a_1, a_2, and a_3 operations. Furthermore, the smallest of the meaningful numbers $\frac{R_{1a}}{b_1}, \frac{R_{2a}}{b_2}, \frac{R_{3a}}{b_3}$ is the maximum number of producible B items under the imposed time limitations following the production of x number of items A; evidently, b_1, b_2, and b_3 indicate the operations on item B on the various equipment (since equipment E_1 is not needed, $b_1 = 0$ in this case).

To find the value of z which designates the quantity to be produced from item C, the above procedure must be repeated, that is, applied to c_j. Let us see now how things work out if the production of item A takes $2+1+4=7$ minutes (that is $7x \leqq 9600$). According to the explanation on page 698, when transformed into an equality, it is $7x + s = 9600$, where s represents the slack variable. If we arbitrarily assume $s = 0$ and we want to produce the maximum amount of item A, then

Step 1:

$$x = \frac{9600}{7} = 1371$$

$$9600 - 2742 = 6858 \text{ on } E_1$$
$$9600 - 1371 = 8229 \text{ on } E_2$$
$$9600 - 5484 = 4116 \text{ on } E_3$$

Now to find out how many units of item B can be produced, the remaining capacity (expressed in time) must be analyzed.

Step 2: $R_{3a} = 4116$, thus $\dfrac{4116}{5 \text{ min}} = 823$ units of B on E_3, that is, $y = 823.2$

$R_{2ab} = 8299 - 823 = 7406$ on E_2

So far capacity utilization versus remaining capacity is as follows:

$$\begin{aligned} 9600 - 2742 \qquad\qquad &= 6858 \text{ on } E_1 \\ 9600 - 1371 - \ \ 823 &= 7406 \text{ on } E_2 \\ 9600 - 5484 - 4116 &= \quad 0 \text{ on } E_3 \end{aligned}$$

Step 3: Since the production of item C depends on the still remaining capacity on E_1 and E_2, let us see what capacity is still unused on E_1 and E_2 which is needed to make z quantity of item C.

$$R_{1a} = 6858 \qquad R_{2ab} = 7406$$

and if c_{21} and c_{22} take up $1 + 3$ min on E_2, respectively, and c_1 on E_1 is 1 min, then $7406/4 = 1851.5$; thus, 1851.5 units of item C can be produced. This will leave the following capacity on E_1, E_2, and E_3 still unused:

$$\begin{aligned} 9600 - 2742 - 1851.5 \qquad\qquad\qquad\qquad &= 5006.5 \\ 9600 - 1371 - \ \ 823 \ \ - (1851.5 + 5554.5) &= \quad 0 \\ 9600 - 5484 - 4116 \qquad\qquad\qquad\qquad &= \quad 0 \end{aligned}$$

The profit equation is the same in both approaches and will be listed under the second approach.

APPROACH 2. In the same manner as before, x, the number of A items, must first be determined. This depends on the total time to process one piece through all three operations. Since it takes 7 minutes to process one piece of A, $7x \leq 9600$, where x represents the number of pieces. To solve this inequality, let us transform it into an equation in one unknown by using s as the slack variable: $7x + s = 9600$, which will permit the solution under the assumption that the maximum of A is being produced ($s = 0$). Thus,

$$\begin{aligned} 7x &= 9600 \\ x &= \frac{9600}{7} \\ x &= 1371 \text{ A's} \end{aligned}$$

When this is multiplied by the profit margin of 70 cents, the total profit is \$960 ($1371 \times \$0.70 = 959.70$). To find the possible profit maximum by making only y quantity of B items, instead of x of A's, the same procedure can be followed. Thus, processing time = (5 minutes on E_3) + (1 minute on E_2) = 6 minutes. The inequality represents a restriction due to the time which the processing of y number of B's will take. Thus, $6y \leq 9600$. By assuming that the maximum amount of B is being produced and that s is used as the so-called slack variable, the inequality is transformed into

$$\begin{aligned} 6y+s &= 9600 \\ 6y &= 9600 \qquad \text{when } s=0 \\ y &= \frac{9600}{6} \\ y &= 1600 \text{ B's} \end{aligned}$$

Since the total profit at this volume on B is coincidentally the same as on 1371 of A items, that is, \$960 (1600 × \$0.60 = \$960), it is evident that profit would not be maximized if item A alone or item B alone were to be produced. Therefore, some of both must be produced to maximize the use of available capacity as well as profit. To ascertain the best plant capacity utilization, the formulas:[8]

$$\sum_{j=1}^{j=3} a_j x \leqq U_a \text{ for item A} \qquad \text{and} \qquad \sum_{j=1}^{j=3} b_j y \leqq U_b \text{ for item B}$$

will give the answer. U represents the amount of time required to manufacture x quantity of A items and y quantity of B items. The same would apply to z quantity of C item:

$$\sum_{j=1}^{j=3} c_j z \leqq U_c$$

where U_c represents the amount of time required to manufacture z quantity of C items. In the inequalities a, b, and c represent the operation time per unit of item A, B, and C, respectively, on equipment j (in the example $j = 1, 2, 3$). It should be remarked that $b_1=0$ and $c_3=0$, since no use is made of equipment E_1 in the manufacture of item B and E_3 in the production of item C, respectively.

After making 1371 pieces of A, the question that arises is how many pieces of items B and C can be produced with the time capacity still remaining. (Capacity is expressed in production time in minutes.)

To avoid working with the inequalities, let us transform them into equations where the products B and C are accounted for, namely, b and c.

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[8] The symbol used for summation is Σ(sigma). Had we added real numbers 1+3+4=8, there would be little need for it. But in algebraic expressions it may be significant. Had we used x_1, x_2, x_3 in lieu of x, y, z or a_jx_1, a_jx_2, a_jx_3 respectively, we should indicate *what* must be summarized. The symbol $\sum_{j=1}^{j=3} x_j$ would, for instance, mean $x_1+x_2+x_3$ or if we wrote $\sum_{j=1}^{j=3} a_jx \leqq T$ it would mean $a_1x+a_2x+a_3x$.

$$\begin{array}{lcl} 2\times 1371 \leqq 9600 & \text{into} & 2742+b_1y+c_1z=9600 \\ 1\times 1371 \leqq 9600 & \text{into} & 1371+b_2y+c_2z=9600 \\ 4\times 1371 \leqq 9600 & \text{into} & 5484+b_3y+c_3z=9600 \end{array}$$

The solution,

$$\begin{array}{lcll} b_1y+c_1z=9600-2742 & \text{or} & b_1y+c_1z=6858 & \text{with } b_1=0 \\ b_2y+c_2z=9600-1371 & \text{or} & b_2y+c_2z=8229 & \\ b_3y+c_3z=9600-5484 & \text{or} & b_3y+c_3z=4116 & \end{array}$$

with the assumption that $b_3=5$, $c_3=0$, $5y=4116$ and y is apparently one-fifth of this:

$$y=\frac{4116}{5}=823$$

Now, on the basis of the above knowledge, the solution to z, under the assumption of d as the slack variable for E_1, is as follows:

$$\begin{array}{lcl} 2742+c_1z \leqq 9600 & \text{or} & 2742+c_1z+d=9600 \\ 2194+c_{21}z+c_{22}z \leqq 9600 & \text{or} & 2194+c_{21}z+c_{22}z+f=9600 \end{array}$$

Remembering that C uses E_2 twice, namely, c_{21} and c_{22}, then,

$$c_1z+d=9600-2742=6858$$
$$c_{21}z=c_{22}z+f=9600-2194=7406 \qquad (f=\text{the slack variable})$$

and if it is assumed that $f=0$, the answer is $4z=7406$ and z must be one-fourth of 7406 or 1851.5.

Accordingly, $x=1371$, $y=823$, and $z=1851.5$ The assumption that $f=0$ should now be repudiated, because c_3z did not turn out to be 6858. Thus, $6858-1851.5=$ a capacity of 5006.5 is still available on E_1.

$$\begin{array}{r} 2742+1851.5+\underline{5006.5} \qquad\quad =9600 \text{ on } E_1 \\ 1851.5+\quad 1371+823+5554.5=9600 \text{ on } E_2 \end{array}$$

In other words, if we had an item D which could utilize 5006.5 minutes on E_1, a 100% utilization of plant facilities would be possible.

Of course, this example has been oversimplified in the sense that no time was allowed for set-up and tear-down time. Obviously, some time might be lost because of such necessary time wastes. Furthermore, the remaining idle time can be used toward the production program of the following month, which would evidently precipitate the same kind of computation.[9]

That this production program is feasible can be expressed by the plant capacity utilization model:

$$a_nx+b_ny+c_nz=T_n$$

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[9] Generally speaking matrix algebra and matrices are more useful than the conventional algebra herein employed (see Appendix G for further explanation).

according to which

$$\begin{array}{lll}
2\times1371+ & 1\times1851.5 & =2742+1851.5=4593.5\\
1\times1371+1\times823 & +1\times1851.5+3\times1851.5 & =2194+7406 \quad =9600\\
4\times1371+5\times823.2 & & =9600 \qquad\quad =9600
\end{array}$$

In the formula, T refers to the total amount of time that equipment n is being used (subscript n denotes a *specific* and j *every* equipment in the production process).

To visualize the production program thus developed, Fig. 15-7 should be studied. The profit can be ascertained according to the profit formula:

$$P=p_ax+p_by+p_cz$$

where the profit made per unit of A is p_a, per unit of B is p_b, and per unit of C is p_c. The maximum profit on this program is therefore

$$\$0.70\times1371+\$0.60\times823+\$0.30\times1851.5=\$2{,}008.95$$

In order to decrease capital costs, the remaining idle capacity on E_1 should be used. Of course, the greater the number of items made the more difficult it becomes to allocate plant capacity between different uses so that conflicts in the use of machines are avoided.

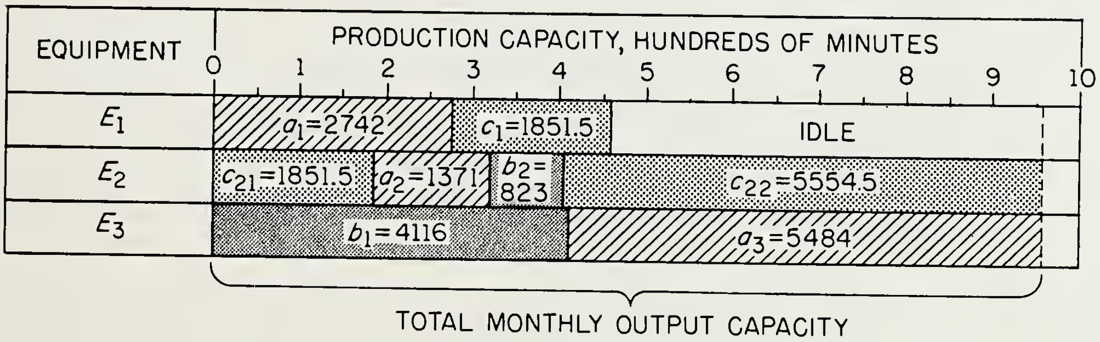

Fig. 15-7

To sum up, it is apparent that either approach 1 or approach 2 would have solved the problem at hand adequately. Approach 1 is a faster method than approach 2. It is apparent, however, that continuous production is not possible because of the imbalance which arises from the fact that each operation ties down equipment for a shorter or longer period of time. To carry out the program overlap scheduling of a_1 and a_2 becomes necessary (Fig. 15-7).

Continuous Production Problem

A brief reiteration will reveal that in this type of production, profitability is a matter of cost control. In view of fluctuating consumer demand (cyclical and seasonal fluctuations), cost control is possible through scheduling of operations so that the cost of production is minimized despite the fluctuating nature of demand. The ideal situation, of course, would be to produce and sell at a steady rate, based on 100% capacity utilization. But, unfortunately, such direct relationship between sales and production is impossible and storage becomes necessary.

If demand fluctuates both above and below plant capacity (assume one-shift operation as being equal to 100% of capacity), it is up to production scheduling to arrange production in such a manner that costs are minimized. Certain cost considerations are apparent. Thus, for instance, 50% capacity utilization tends to cut labor and material costs in the same (nearly the same) proportion, but the fixed costs tend to remain at their normal level. In contrast, a peak demand, requiring approximately 50% more output (if done through overtime work), would cause at least 50% increase in labor costs per unit of output, whereas the fixed costs would be falling because the same cost can be divided among a larger output. The storage and related costs (insurance, interest charges on capital invested into inventory items, etc.) would also rise because the out-of-pocket expenses for added warehousing facilities, greater interest charges on working capital, etc., would add to costs.

To sum it up, for handling demand fluctuations there are basically two alternatives. Each would necessitate careful weighing of costs associated with them.

Regardless of which alternative is employed, both company objectives, namely, supplying the market and doing so with the lowest cost of production, must be attained. Emphasis is on supplying the market, yet low-cost operations are equally important. The production target is supplied by the sales forecast. Unless a producer furnishes toothpaste, for instance, as required by the sales forecast, sale and the profit margin the price contains is lost. A customer wants to pick the product off the shelf; if it is not there, he selects another brand.

It should be noted that mass producers tend to be in stiff competition with one another and, because of the competitive nature of business, price is more or less established by market forces rather than by the manufacturers. Because price is relatively independent of internal control, profit can be maximized primarily through minimizing costs. Profit then depends on sales volume and profit margin; the latter, in turn, depends on costs.

The problem of the planner in continuous production is clear: always meet demand, yet do so at the lowest cost consistent with overall company goals. To achieve this dual goal, several important cost parameters (influencing factors) must be selected and used as the criteria of measurement in order to establish production and cost levels. Basically, two policies can be followed:

1. Production in light of demand (shut down if demand does not warrant operations; work overtime when demand is in excess of normal one-shift plant capacity.)
2. Produce always at capacity (constant rate of flow) and absorb fluctuations in sales by building up or depleting inventories as the case may

be. Of course, if, in the long run, capacity is greater than demand, a shutdown becomes necessary at some point even in this method of operations on account of the $Q < 10$ million ton inventory policy.

Each manufacturing policy precipitates a different cost structure. Generally speaking, the total costs can be broken down into labor (C_l), material (C_m), storage (C_s), and fixed costs (C_f). Although in a real situation it is essential to break down the above costs even in smaller cost elements (such as direct and indirect labor; labor cost if overtime, second shift, or third shift differential, etc. would be applicable), the present example will be restricted to the broad cost classification of labor, material, storage and fixed costs. It should be emphasized, however, that a further refinement of the various cost factors may, in many instances, precipitate substantial differences in costs. For instance, a curtailment in production may cause a proportional cutback in direct labor costs, but still not in the same proportion with indirect labor such as maintenance and materials handling.

The *first alternative* depending on prevailing economic conditions consists of two parts: 1) shutdown to prevent overproduction, excessive storage costs, and costs associated with storage or 2) overtime work to meet peak demand. Depending on the action, cost will differ. Thus, a shutdown does not eliminate fixed costs, though some segments of overhead might show a falling tendency in light of declining output. In the following calculations, however, the variable aspects of some fixed costs will be neglected, simply because we have to oversimplify matters in this example, and not because the latter would not be important. While *most* of total *labor cost* will be eliminated, indirect labor cost will, as mentioned previously, not change proportionately with the rise and fall of production. Barring the effects of quantity discounts, material cost will, however, fall at the same rate as that at which production is being curtailed or suspended. But storage will weigh heavily on total cost depending on how long the shutdown lasts and on the depletion rate of stored inventories (backlog of inventories). Special attention must be paid to storage costs since they are partially fixed, partially variable. The latter tend to rise faster than the accumulation of inventory. With *overtime work* certain fixed costs tend to fall, however. This can evidently be attributed to a larger number of output units, which are capable of absorbing more of the fixed costs than would be possible under normal operating conditions. In connection with fixed costs, the policy may set the restriction that shutdown should not take place unless at least the fixed costs are taken care of (covered). But this is a refinement.

Labor costs tend to increase at least by 50% because of the time and a half pay C_{l_2}. However, also other than direct labor costs might be associated when increasing output beyond the plant's original capacity (C_{l_3}, C_{l_4}, etc.). These are neglected here for the sake of simplicity.

Material costs tend to remain relatively stable per unit of output, barring the influence of certain price concessions due to quantity discounts (C_{m_3}).

However, the simplified cost curve in Fig. 15-8 does not indicate such an eventuality.

Storage costs C_s tend to rise because of rising interest charges, insurance, added warehouse rentals, greater degree of obsolescence (to be ascertained by means of the probability theory), damage to inventory, etc. Depending on how these factors would influence them, the costs can be broken up into a series of cost parameters and given appropriate designations of C_{s_2}, C_{s_3}, etc.

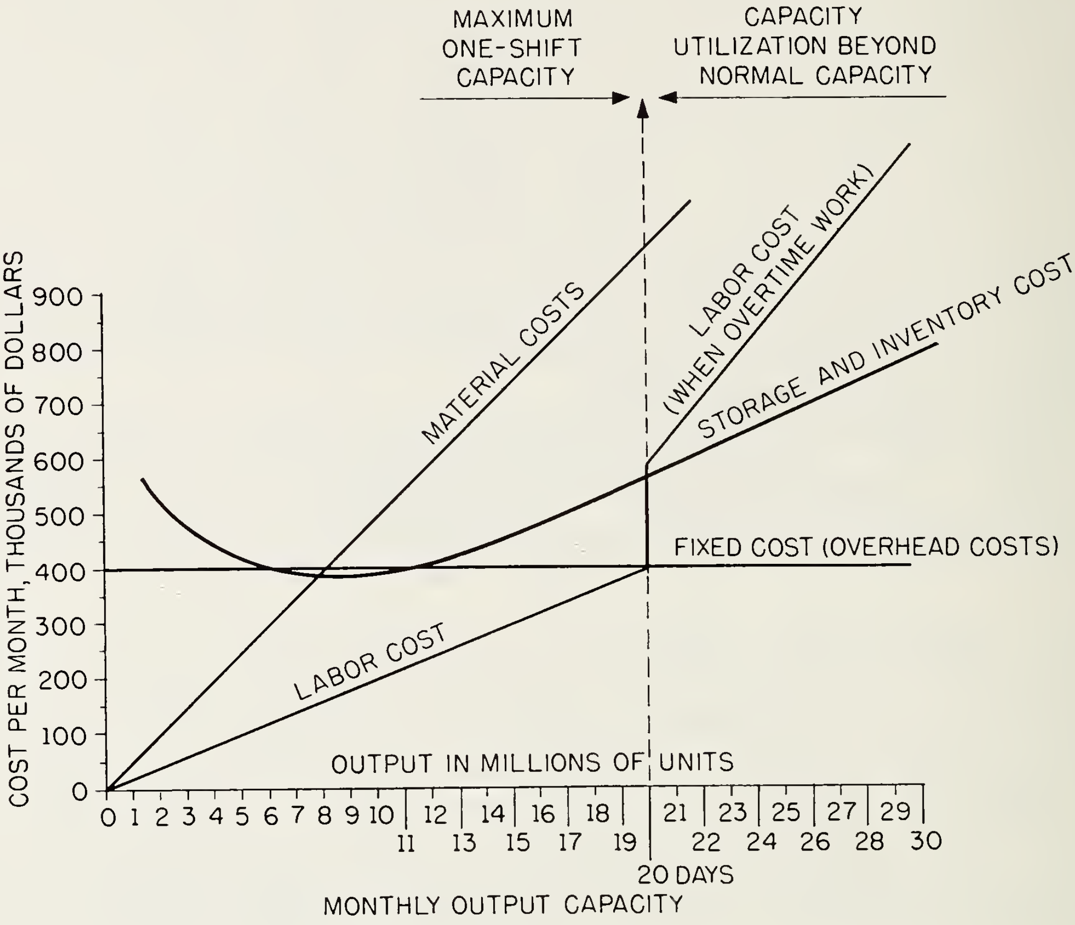

Fig. 15-8

The *second alternative* would have relatively constant costs as far as C_l, C_m, and C_f are concerned. The storage cost C_s, however, would be extremely important; particularly during periods of slack demand. Apparently, storage and related costs (C_{s_2}, C_{s_3}, etc.) would weigh heavily on the managerial decision. Let us assume the cost factors (highly oversimplified) shown in Fig. 15-8.

Problem 3. The current inventory position of a company engaged in continuous production is 5 million tons (the product in question could be anything and is of no importance whatever). The fact creating the problem is that sales tend to fluctuate with the business cycle on the one hand and with the seasonality of demand on the other hand. The sales forecast to which production must be gaged is shown in Table 15-4.

TABLE 15-4

TWELVE MONTHS SALES FORECAST

Month	1	2	3	4	5	6	7	8	9	10	11	12
Quantity	18	18	18	20	25	25	18	15	15	15	15	15

The costs associated with given production levels must be ascertained from the company's cost curves based on past experiences. In normal practice, the cost curves are revised after each contract (labor contract) negotiation or when major changes either in raw material prices or in any other cost element take place.

Storage cost requires some degree of additional calculation because current output must be added to the inventory carryover from a preceding production period (for example, the sales estimate could have been inaccurate or all output units were not sold and hence material must be stored). The inventory status depends, therefore, on the current inventory position I plus the output quantity Q in any given month. From this total, the sales must always be deducted. (In the example which follows, it is essential to assume that the sales forecast is correct and that all output units will indeed be sold). This assumption would, in practice, seldom be valid and would influence the current inventory position. Nevertheless, for the sake of simplicity, in the case which follows, it should be neglected and it should be assumed that all output units are sold. Accordingly,

$$I+Q-S \text{ (sales)} = Q_s \text{ (quantity to be stored)}$$

Obviously, the storage cost must be based on Q_s. Once this is ascertained, the storage cost can be read off the curve in Fig. 15-8.

The various cost curves in Fig. 15-8 are not related to one another in the sense that their intersection would mean anything. Four different curves are simply plotted on the same diagram to save space.

According to the company's inventory policy, the carryover quantity from one production period to the next should not exceed 10 million tons (restriction). How this should be calculated has already been given in Chapter 12, pp. 534-535. The fact that if maximum inventory accumulation has been reached, production must cease is important.

In the following equations, C_Q represents the cost of the volume to be produced and the symbols C_{f_1} and C_{f_2} represent the fixed costs. Specifically, C_{f_2} represents the difference between the overtime fixed cost and normal-capacity fixed cost, and $C_{f_2}=0$, of course.

C_{v_1} is the sum of all variable costs, but it depends largely on the value of Q_s, the quantity in storage. $Q_s<10$ denotes the inventory policy of the company. According to this, the quantity kept in the storage room cannot exceed 10 million tons (restriction).

C_{v_2} represents the increase over the normal variable operating cost (that is, C_{v_1}) when overtime work becomes necessary. This would be applicable only in alternative 1, since alternative 2 is based on a steady output rate.

C_{l_1} represents the cost per million tons resulting from labor costs under normal operating conditions; overtime work is represented by the symbol of C_{l_2}; conversely, C_{m_1} represents the material costs until normal. When beyond normal output C_{m_2} represents the difference between the added material cost resulting from greater output.

$f_{sc}(x)$ represents the cost function as far as storage costs are concerned. Apparently, the cost will vary with the size of the quantity stored and must be read off the cost curve in Fig. 15-8. $f_{sc}(x)$ is, of course, a composite of storage cost under the conditions of normal and abnormal production.

Alternative 1.[10] a) Shut down rather than overproduce or b) overtime work to meet peak demand.

a. Shutdown

$$C_Q = C_{f_1} + C_{v_1} \qquad \text{with } Q_s < 10 \text{ million tons}$$

and

$$C_{v_1} = xC_{l_1} + xC_{m_1} + f_{sc_1}(x)$$

where x = millions of tons,
C_{l_1} = the cost of labor per million tons,
C_{m_1} = the costs of materials per million tons.

b. Overtime work

$$C_Q = C_{Q_1} + C_{Q_2}$$

that is,

$$C_Q = C_{f_1} + C_{v_1} + C_{f_2} + C_{v_2} \qquad \text{where } C_{f_2} = 0$$

and

$$C_{v_2} = xC_{l_2} + xC_{m_2} + f_{sc_2}(x)$$

with $Q_s < 10$ million tons

The final equation, taking all possibilities into consideration then becomes

$$C_Q = C_{f_1} + C_{f_2} + (C_{l_1} + C_{l_2} + C_{m_1} + C_{m_2}) + f_{sc}(x)$$

with

$$f_{sc}(x) = f_{sc_1}(x) + f_{sc_2}(x)$$

Alternative 2. To reiterate, operate at capacity (20 million tons per month) all the time and absorb fluctuations in demand by building up and depleting inventories as the case may be. The cost function is

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[10] This example appeared in an abbreviated form *Zeitschrift für Betriebswirtschaft* (Wiesbaden, Germany), July-August, 1962, Vol. 32, no. 7/8, pp. 402–418, as a part of an article entitled "Operations Research im Industriebetrieb, Zum Problem Optimaler Kapazitätsausnutzung," written by the author.

$$C_Q = C_f + C_v \qquad \text{with } Q_s < 10 \text{ million tons}$$
$$C_v = xC_l + xC_m + f_{sc}(x)$$

To work out the problem, the fact that labor cost per ton and material cost per ton must be taken into consideration is important. Accordingly, labor cost = \$20,000 per million tons; when overtime is scheduled, that portion of the cost falling on the output quantity exceeding the 20-million-capacity limit must be calculated on the basis of \$30,000 per million tons. Material cost per million ton is equal to \$50,000 per million tons. Fixed costs are \$400,000, and the storage cost must be read off the storage cost curve.

Accordingly, the first 18 million costs:

$$18 \text{ million tons} = \$400 + 18\ (\$20 + \$50) + \$650, \text{ in thousands}$$
$$C/18 = 400 + 360 + 900 + 650 = \$2,310,000$$

Based on the same calculation for every output period (12 months), the costs of the production program for 12 consecutive months are as shown in Table 15-5.

TABLE 15-5

Cost of Production Program for Twelve Months

Mo.	1	2	3	4	5	6	7	8	9	10	11	12
PQ:	18	18	18	20	25	25	18	15	15	15	15	15
Alternative Program 1												
F	400	400	400	400	400	400	400	400	400	400	400	400
L	360	360	360	460	550	550	360	400	300	300	300	300
M	900	900	900	1100	1250	1250	900	750	750	750	750	750
S	650	550	550	580	700	700	550	450	450	450	450	450
TC	2.31	2.21	2.21	2.54	2.90	2.90	2.21	1.9	1.9	1.9	1.9	1.9
Alternative Program 2												
F	400	400	400	400	400	400	400	400	400	400	400	400
L	400	400	380	400	400	400	400	400	360	200	400	300
M	1000	1000	950	1000	1000	1000	1000	1000	900	500	1000	750
S	700	750	760	800	800	700	580	620	700	580	700	700
TC	2.52	2.55	2.49	2.6	2.6	2.5	2.38	2.42	2.36	1.68	2.5	2.15

PQ = Sales forecast production quantity, millions of tons
F = fixed costs, hundred thousands
L = labor costs, hundred thousands
M = materials costs, hundred thousands
S = storage costs, hundred thousands
TC = total costs, millions

Alternative program 2 implies high inventories carried in stock (up to the maximum of 10 million tons). Since production will not go beyond the maximum inventory position, at those points layoffs are scheduled. Figure 15-9 illustrates the production program based on the sales forecast and the maximum inventory policy. Due to excessive inventory build-up, layoffs become necessary.

According to the following calculations, the monthly output requirement can be achieved with the following costs:

$$\text{Cost}/18 \text{ million tons} = \$400 + 18\ (\$20 + \$50) + \$700 \qquad \text{in thousands}$$
$$C/18 = \$400 + \$400 + \$1000 + \$700 = \$2{,}500{,}000 \text{ per } 18 \text{ million tons}$$

If all calculations are carried out for the 12-month period, the cost structure in Table 15-5 is obtained.

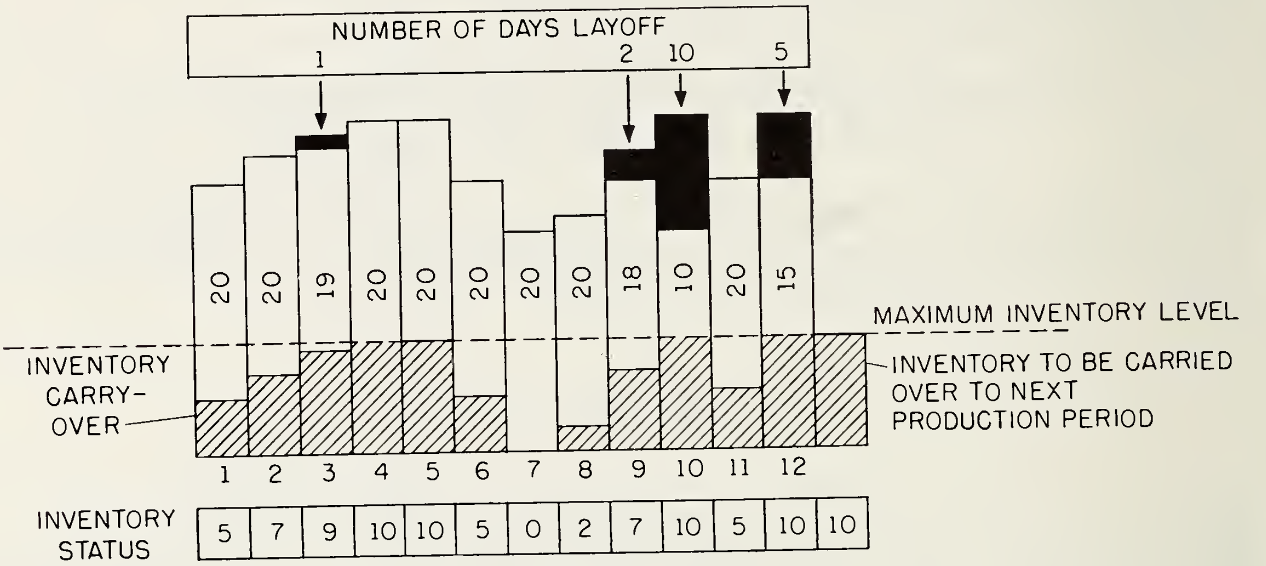


FIG. 15-9

A comparison of the two alternatives immediately reveals that the total yearly output of 217 million tons costs with

Alternative 1......	$26,780,000	at 1234¢ per ton
Alternative 2......	$28,730,000	at 1324¢ per ton
	$ 1,950,000	

Thus, a saving of $1,950,000 can be achieved by following alternative method 1. Obviously, out of this preaudit other important conclusions can also be drawn (for example, labor contract considerations), in addition to manufacturing policy.

COMPUTER AND OPERATIONS RESEARCH

The preceding examples have one or two things in common: they all deal with a limited number of goals and few factors must be considered. In a real situation this would not be the case. Real-life production situations contain so many variables and so many comparative factors that in most instances a calculation by conventional methods (that is, using paper and pencil and possibly a desk calculator) would take much too long time to make the computation feasible. For example, the job shop problem worked out contained merely six operations and six orders; the repetitive production problem dealt with three items and three machines, in addition to the time study data and the fact that a dual goal had to be attained; in the continuous manufacturing example, one item is stored and carried in inventory instead of hundreds and a few cost parameters only were taken into consideration. Evidently, then, in a real-life situation a high-speed computer must be used in order to take advantage of the operations research method.

One should not assume, however, that the feasibility of the paper-and-pencil computation is unimportant. The computer is only as accurate as the calculational model or program. The general computational method must be worked out on paper, but the routine of making all essential computations must be transferred to the computer. The latter is nothing but a time saver. Therefore, computer answers must initially be checked by hand calculations to obtain validity of the program. Of course, once the validity of the model is certified, the computer rarely makes a mistake as long as the input data are correct.

The computer, as mentioned in the preceding chapter, consists of several parts: 1) input-output unit, 2) memory unit, and 3) the calculator unit, all linked together electronically. All parts function, however, as one big machine. In operations research work, the memory unit would retain the model—the basic modus operandi for the solution of the problem. The information necessary to carry out the mathematical computations is, however, furnished to the input unit, which, via the computer and the model, will digest the raw data.

Although the algebraic explanation is used in this chapter to describe the operations research technique, most operations research problems use methods designed for computer applications, as Appendix G and some of the case studies which follow will indicate. All operations research problems could easily be handled algebraically, but the table on which the data must be arranged is usually so designed that the computer can read it with facility.

The model (the mathematical formula) as well as the raw information which the computer must digest, will have to be given, that is, translated into a symbolic form. The latter is used because the computer is only an electronic device and it is possible to instruct it to do certain computations only in a manner it can readily understand. The information to be plugged into the formula, and the formula itself, must therefore be in a coded form. As the computer works out the answer, the latter is typed out, usually also in a coded form—though nowadays a decoding device converts it simultaneously to a normal language the people can understand. In summary, then, instruction to and answer from the computer is in FORTRAN (FORmula TRANslation) "language," which is one of the many special code-systems designed for computers.

SUMMARY

PREAUDITING THROUGH OPERATIONS RESEARCH

In the final analysis, profit depends on the excellence of the managerial decision. This is true whether we are dealing with a job shop, a repetitive shop, or a continuous production shop. Since only the introduction of the most promising action will lead to the greatest degree of profitability, it is essential to determine which *is* the best course of action in advance of performance. To this end operations research was invented. It should be noted, however, that the military had used it prior to business, but for different purposes.

Operations research is predicated upon the assumption that no one can tell in advance with any degree of accuracy which of a multiplicity of promising possibilities is the best method. Since the conventional decision-making method of the past using primarily a rule-of-thumb approach where seasoned judgment was the primary tool is no longer considered sufficiently accurate to assess future happenings, recourse is made to mathematical techniques to preplan and preaudit the possible outcome of any given action. These methods are summarized under the term "operations research."

LIMITATIONS OF OPERATIONS RESEARCH

Basically, operations research cannot do more than the human being is able of doing when appraising something in light of current knowledge. However, operations research is able to make a *more accurate* comparison among different factors than the planner who manipulates factual data in his head. Since operations research techniques formalize the decision-making and associated planning process, the chances are that all factors will be considered no matter how small or apparently insignificant. The assumption is that decisions are often made on the basis of expediency whereby some of the minor factors are disregarded and only the major factors—and, even then, primarily the tangible factors—are considered. The claim is made by operations research experts that in operations research every factor is considered and weighed equally in the solution of the problems. By doing so, every influencing factor is properly evaluated and the possibility of misjudgment and errors is largely eliminated.

However, operations research does not do anything more than common sense can do; it merely does it with a greater degree of accuracy. The human mind is at a handicap when too large a number of factors must concurrently be considered, whereas the mathematical method is equally at home with a large number of influencing factors—particularly when the electronic computer takes over where the operations researcher left off. But, if the factors with which the computer works were erroneous, the answer tends to be equally erroneous. The data necessary for the decision must be accurate in order to expect accurate answers from the operations research techniques.

EVALUATION OF THE EXAMPLES

Since operations research deals with different problems in all fields of industrial endeavor, it encompasses many areas of the production planning and control work. Examples given were related to the three different industrial situations of intermittent, repetitive, and continuous production. These examples were, however, oversimplified in that the answer could have been found just as easily with charts and graphs and through recourse to common sense.

A case in point is the first example and, for that matter, the example dealing with repetitive production. A decision with Gantt charting would have permitted calculation of the schedule in question without providing information about profit possibilities. Operations research, on the other hand, permitted a simultaneous dealing with multiple variables and goals. Indeed, none of the orthodox methods permits determination of the best possible action if the number of variables exceeds a certain maximum of three or at most four. The third major example dealing with continuous production would have been more difficult to determine without use of operations research techniques, yet the complicated decision-making process was a simple one with mathematical techniques. Therefore, the main advantage of operations research techniques is that they permit solution of involved problems with multiple restrictions and goals. Actually, in each case we could have calculated profits without operations research techniques, but only in retrospect.

OPERATIONS RESEARCH AND INTANGIBLE FACTORS

Orthodox decision-making methods do not permit decisions about "intangible" factors; or if they do, the decisions usually do not amount to more than educated guesses without any assurance of validity. With mathematical-statistical techniques, however, even those problems which are primarily of qualitative character can be brought to a satisfactory solution. A case in point can be found in the examples given in the preliminary explanation, where intangible factors are quantified and serve the decisional process. Of course, unless these factors are quantified they are useless in the ordinary sense for decision-making purposes.

Similar to the intangible factors are the unknown or semiknown factors used in the decision-making process. When a factor must be assumed to find the unknown factor or the semiknown factor, certain other assumptions must be made. Without such assumptions, the problem cannot be solved. Instead of using arbitrarily assumed factors, the operations researcher might take recourse to statistically fabricated data. They can then be used and several alternative solutions can be determined depending on the assumptions made.

Since these assumptions are statistically valid, the chances are that the calculated outcome of actions will turn out to be correct. Of course, the operations research method will give several alternative possibilities and it is still up to the planner to select from among them the action likely to succeed. In this process, alternatives are appraised in terms of predicted outcomes and evaluated according to some acceptable scale of desirability. Ordinarily that action will be selected which maximizes (or minimizes) both the probability of attainment and the results desired. Since the above two are not necessarily concomitants, a highly desirable action with little likelihood of attainment will, of necessity, be superseded by a less desirable action with a greater degree of chance for success. Furthermore, if some limiting factors prevent the application of the best course of action, it follows that the planner will select the next best action. The latter is exemplified by the first example which was explained.

The Merit of Operations Research

It is a distinct merit of operations research techniques that they tend to formalize the thinking and planning process by using paper and pencil to manipulate the factors used in the contemplation. If a computer is used, it not only assures comparison of every factor in light of relative merits, but also attains speed so essential in many decisional processes. Last, but not least, mathematical methods through the matter of quantification tend to foster objectivity as opposed to the subjective nature of rule-of-thumb methods of planning and decision making.

QUESTIONS

15-1. How do you define operations research and linear programming?

15-2. What is the relationship between operations research work and the probability theory?

15-3. What is the main difference between the rule-of-thumb methods of planning and operations research techniques?

15-4. What are the basic deterrents to the application of operations research in production planning and control work?

15-5. Does or does not operations research have a place in every industrial enterprise?

15-6. How much importance should be attached to the various operations research techniques?

15-7. What basic mathematical concepts are used in operations research work?

PROJECTS

15-1. A company receives six orders, A, B, C, D, E, and F, for 2000, 4000, 3000, 3500, 4500, and 2500 pieces, respectively. According to the time study data, each of the six machines capable of performing the *first* operation (out of ten operations) on every one of these orders, can accomplish the operation with different efficiencies as shown in the accompanying table.

Order	M_1	M_2	M_3	M_4	M_5	M_6	M_7
	Time Study Data, hundredths of minutes						
A	0.10	0.15	0.20	0.25	0.30	0.40	0.50
B	0.50	.15	.10	.20	.25	.30	.40
C	.20	.25	.30	.40	.50	.10	.15
D	.25	.30	.35	.40	.45	.20	.20
E	.20	.20	.15	.15	.20	.30	.15
F	0.30	0.35	0.30	0.20	0.20	0.35	0.35

Machine M_7 can be used if absolutely necessary; otherwise it should not be touched.

The products in each order must be routed through the first operation so that the lowest time requirement is achieved overall. Only operation 1 is done here, the same procedure would, however, apply to all the other operations.

The company does not produce broken lot quantities, unless it cannot be avoided. Thus, the whole of each order should be routed through the same machine if at all possible.

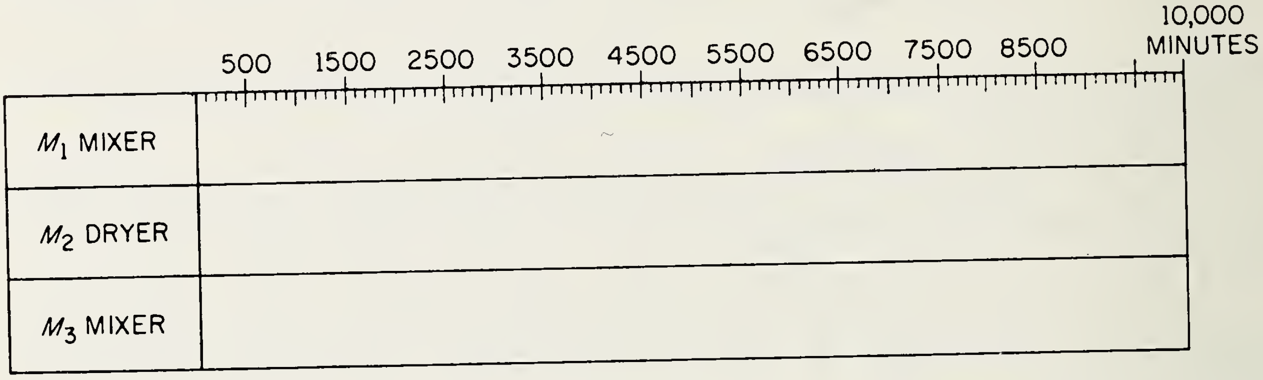
The plant does not like to work overtime because the cost of production is of paramount importance. All above operations should therefore be completed within one day (480 minutes).

Indicate the timewise and costwise best allocation of the workload among machines. Under which conditions would overtime work be cheaper than any other arrangement?

15-2. A further refinement of Project 1 can be made by checking your project to find a situation in which the planner had to make a decision on the machine to pick (for example, two machines were equally well qualified to accomplish the purpose on two different orders). By keeping the following "importance factors" in mind, make your correction: A, 0.5; B, 0.8; C, 0.4; D, 0.7; E, 0.6; F, 0.9. The importance factor reflects the relative importance of a contract (order) to the company in terms of desirable customer (for example, General Motors might be more important to a company than an unknown customer who occasionally gives a small and relatively small profit margin order). Which order could be postponed in case a rush job would come along requiring M_2 and M_3 machines for a total of 500 minutes?

15-3. A repetitive producer engaged in the production of pharmaceuticals decided to drop four items from its line of products (some wonder drugs made them obsolete). To utilize the machine capacity thus idled, there are several items which can take their place, namely: Promomile (P), Revemint (R), Germazon (G), and Huron (H). The company has no preference because the quantity which the equipment within the 10,000 minutes per month (capacity) can turn out can be sold. If a larger quantity than one batch per month were produced, it would be difficult to sell all output units. Thus, only one batch from each item should be made per month.

The production of these items requires the services of a mixer and a drying machine. There are two mixers which can be used interchangeably. Although there is some time loss between runs (for purposes of clean-up) this is neglected in the problem. In case some time on the machines is still available, two other products might be scheduled, Bromide (B) and Nexagol (N). The process sheet shows the preferred mixer, though mixers M_1 and M_3 can be used interchangeably (see the accompanying illustration).



In the accompanying diagram the subscripts 1, 2, 3, represent the type of machine to be used on that item. The numbers under the process indicate the operation sequence (where an alternative process is permitted, it is illustrated on the chart).

PRODUCTION PROCESS AND OPERATION TIMES

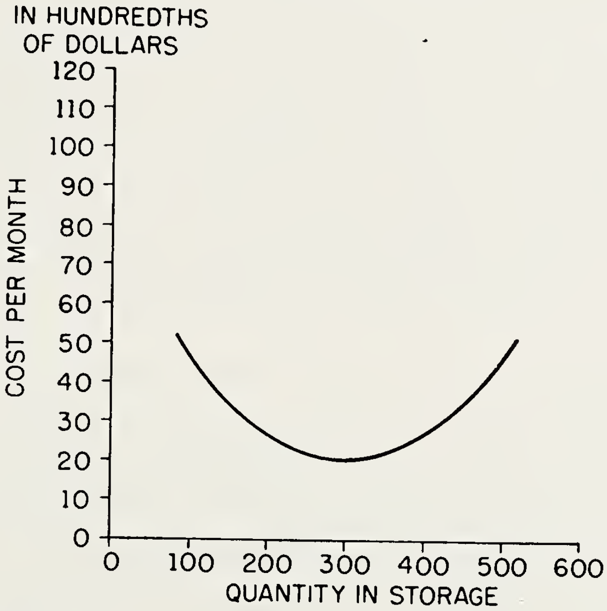
Item	Process					Operation Time				
	1	2	3	4	5	1	2	3	4	5
G	G_1 G_3	G_3 G_1				150				
H	H_2	H_3	H_2	H_3		200	200	300	100	
P	P_1	P_2	P_3			200	300	200		
R	R_1 R_3	R_3 R_1	R_2	R_1 R_3		150	100	200	200	
B	B_2	B_3				100	100			
N	N_2	N_3				150	50			

Profitability depends largely on capacity utilization. Therefore, the more items can be scheduled for production, the better will be the distribution of the fixed costs. How should the equipment be allotted among these products?

15-4. A continuous producer having the policy of keeping a maximum of 300 units in stock (minimum 100) has the sales forecast for the coming 12-month period that is shown in the accompanying table. We shall assume that the forecast is perfect and that all units will be sold.

The task of the production scheduling group is to accomplish production at the best cost structure. The costs of production to be taken into consideration are as follows:

a. Fixed cost $300,000 per year.
b. Material cost $35 per unit.
c. Labor cost $40 per unit until the monthly capacity of 600 units per one shift; any production above 600 units per month would raise the labor cost by $20 per unit.
d. Storage cost, including inventory carrying charges, should be read off the curve in the accompanying illustration.



The maximization of profit can be achieved through the minimization of costs. Thus, minimum cost and availability of goods according to the sales forecast are the two objectives.

Period	1	2	3	4	5	6	7	8	9	10	11	12
Inventory carry-over from preceding period, 200	500	400	400	450	500	500	600	600	650	600	550	500

The labor union is very cooperative and agrees with management's scheduling arrangements. However, their idea is that either everybody is laid off or everybody is on the job.

Schedule production in light of the two objectives.

15-5. Explain as best as you can how Projects 1, 2, 3, and 4 could be accomplished with the help of a high-speed electronic computer.

Suggest methods of programming and work out some system of codification whereby the production control function could be transferred to an electronic machine.

What information should the memory unit retain and what information must be given to the electronic computer so that it can work out the best plan?

CASES

15-1. THE UNION RAILROAD COMPANY[11]

A young engineer's suggestion to make better use of work crews and locomotives at the Union Railroad Company is under consideration. The suggestion was precipitated by a recent railroad problem due to a steel strike. Since some of the most important customers of the Union Railroad Company are the steel companies in the Pittsburgh district, when there is a steel strike, the need for switching services the Union Railroad Company renders is greatly curtailed. As a result, an ineffective use is made of both crew and locomotive. Ordinarily, the locomotives and crews are sent to certain locations to move a given railroad car located along a predetermined route. During the strike, the steel companies do not commission the URC and therefore, each crew makes fewer pickups on its route. Thus, the cost of a crew and the locomotive must be distributed among fewer users, which tends to make some trips unprofitable. To reduce costs, it is attempted to make more pickups by fewer crews.

A switching railroad, such as the Union Railroad Company, operates similarly to a job shop, in that it merely places its facilities at the disposal of the customer. Customers may want a carload full of goods switched from one track to another or from a railroad siding to the receiving docks of its receiving department. Often the railroad car is not unloaded until the goods it contains are actually needed in production, but when there is a need, a locomotive must be sent out to move the car where needed. Here is where the Union Railroad Company's services are needed.

Most manufacturing companies cannot very well afford to own their own locomotives and hire crews for such purposes. It is evidently cheaper to hire the services of a switching railroad. The railroad is called up and requested to send out a locomotive to move a railroad car from somewhere to somewhere else. Where the railroad car is located and where it must be moved are told to the railroad dispatcher. The customer gives the time when the car must be moved, and it is of extreme importance that the move is made in accordance with the customer's time table. Thus, the move must be made within a few hours—often within an hour. As the locomotive arrives, it moves the railroad car or cars in question as directed, hauls it, or them, over a longer railroad stretch to another plant or to another railroad bed to be hooked up to a regular freight train taking it, or them, directly to a distant destination. In other words, the switching railroad is commissioned to do something definite with the railroad car or cars in question for which the company has a predetermined fee.

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[11] The author is indebted to Ronald C. Rush, of the Industrial Engineering Department of the Union Railroad Company, for his help in preparing this case study, particularly for checking the accuracy of the information which it contains.

When there is a steel strike, the demand for crews is greatly reduced, yet the crew must still make its normal round much as a mailman must make his customary round. Whether the crew and the locomotive must make many pickups or only a few along the same general route is no concern of the customer. As far as the switching railroad is concerned, however, less business handled by each crew means higher cost per customer. Thus, the fixed cost will, of necessity, be distributed among fewer units.

When along a route only five load assignments are being picked up, a crew must still be sent out to pick up the railroad cars as instructed. Ordinarily the same crew would probably pick up 50 cars as it passes by given points. Thus, it costs the railroad company the same for the crew whether it picks up 10% or 100%. It must be apparent by now that the less pickup is made by each crew, the higher is the cost of doing business (the locomotive must be heated up, the crew must be called in and paid) and by the same token, the smaller is the revenue. Occasionally, it costs the railroad company more to pick up a car than its revenue warrants. But, of course, the railroad is a service-rendering organization and it must perform the service *promptly* if it wants to stay in business. It would occasionally be better to refuse to pick up a car (if it were to cost more to do so), but of course profitable or not, the car must be picked up and hauled to the point in accordance with the instructions.

What the railroad can do, however, is to design a method which will permit an effective scheduling of crews in the sense that each crew is assigned as many pickups as it can possibly handle during a normal turn. A young industrial engineer proposed to the railroad an effective method of scheduling of train crews on a daily basis with the help of linear programming. According to his proposal, the railroad could, by using his method, get the most mileage out of both crew and locomotive. It should be understood that often a crew makes a "round" with a locomotive and bypasses a point where it could have made a pickup but did not do so because it could not handle so many pickups in the available time. Thus, at a later time but still during the same day another crew must be sent out to pick up that car. It is obviously awfully costly to make two pickups when the load could have been picked up in one sweep. But, with the present method of scheduling, it is not easy to see the situation clearly enough to make the most effective use of crews.

The crews are on call duty. If not called, they are not paid. If they are called and make only a few pickups, they must be paid as much as if they had done a good day's work. It is, of course, not the crew's fault that they make only a few pickups; the presently used orthodox method of scheduling crew assignments is responsible. According to the industrial engineer proposing the linear programming method, on a typical day the crew size could have been reduced from 37 to 33 or even to 29. In other words, 33 or 29 locomotives could have been sufficient to make 74 pickups (loads) had the linear programming method of scheduling been in operation. The reader should examine Fig. 1 to see the possible results.

The Union Railroad operates in an area in Allegheny county of approximately ten miles radius and has 500 miles of mainline and yard track. It interchanges with seven different trunk-line railroads at 24 interchange points. On

TEST APPLICATION OF LINEAR PROGRAMMING TO
U.R.R. TRAIN MOVEMENTS FOR APRIL 20, 1956

	Actual Moves			
Starting Point	Route	Crew	Loads	Light
First Turn				
Bessemer	2,7,4,1	1	3	1(1-2)
Bessemer	2,5,7	1	2	1(2-5)
Bessemer	2,3,7,3	1	2	2(2-3)(3-2)
Bessemer	2,3,5,1	1	2	2(2-3)(1-2)
Bessemer	2,3,4,5	1	2	2(2-3)(5-2)
Hall	1,2,4,7,4	1	4	1(4-2)
Mon Junction	4,5,4,6,5	1	3	2(4-5)(5-4)
North Bessemer	1,3	1	2	
North Bessemer	1,2	1	2	
Clairton	7,5,2	1	2	1(5-2)
Bessemer	2,1,3	1	2	1(3-2)
Irvin	7,2,5	1	1	2(2-5)(5-7)
Mifflin	6,4	1	2	
Totals		13	29	15
Second Turn				
Bessemer	2,7,1	1	1	2(2-7)(1-2)
Bessemer	2,7,4	1	2	1(4-2)
Bessemer	2,5,7,3	1	2	2(2-5)(3-2)
Bessemer	2,5,1,5	1	2	2(2-5)(5-2)
Bessemer	2,3,6,4	1	2	2(2-3)(4-2)
North Bessemer	1,4	1	2	
North Bessemer	1,2,1,2	1	2	2(2-1)
Bessemer	2,3,4	1	2	1(4-2)
Clairton	7,4	1	1	1(4-7)
Mifflin	6,1	1	2	
Mon Junction	4,5,4,6,5,6	1	3	(4-5)(6-5)(6-4)
Mon Junction	4,2,4	1	2	1(7-4)
Mon Junction	4,3,5,7	1	3	1(7-4)
Totals		13	26	18
Third Turn				
Bessemer	2,7	1	2	
North Bessemer	1,2	1	2	
Clairton	7,5,4	1	2	1(5-4)
Irvin	7,4	1	1	1(4-7)
Mon Junction	4,3,7	1	2	1(7-4)
Irvin	7,6	1	2	
Mifflin	6,3	1	2	
Munhall	5,3	1	1	1(3-5)
Munhall	5,3	1	1	1(3-5)
Duquesne	3,5	1	2	
Valley Yard	2,1,7	1	2	1(1-7)
Totals		11	19	6
Grand Totals		37	74	39

OR Scheduling Moves			
Route	Crew	Loads	Light
First Turn			
1,2	1	2	
4,6	1	2	
1,2,7	1	2	(7-1)
1,3,4	1	3	
1,3,5	1	3	
1,7,2	1	2	(1-7)
1,7,3	1	2	(1-7)
2,4,7	1	3	
2,7,4	1	2	(4-2)
3,7,5	1	2	(5-3)
4,5,7	1	3	
4,6,5	1	3	
Totals	12	29	5
Second Turn			
2,4	1	2	
1,2,5	1	2	(2-5)
1,2,7	1	3	
1,4,6	1	2	(6-1)
1,5,6	1	3	
1,6,4	1	3	
2,3,6	1	2	(6-2)
3,4,7	1	2	(4-7)
3,5,4	1	3	
4,5,7	2	4	2(4-5)
Totals	11	26	6
Third Turn			
1,2	1	2	
2,7	1	2	
3,4	1	1	(3-4)
3,5	2	3	(3-5)
3,6	1	2	
4,7	1	2	
6,7	1	2	
1,7,2	1	2	(1-7)
3,7,5	1	3	
Totals	10	19	3
	33	74	14

OR Scheduling Moves 24-Hour Period			
Route	Crew	Loads	Light
1,2	2	4	
4,6	1	2	
1,2,4	2	6	
1,2,7	1	3	
1,3,5	2	6	
1,4,6	1	3	
1,5,6	1	2	(6-1)
1,6,3	1	3	
1,7,2	2	4	2(1-7)
1,7,6	1	1	(1-7)(6-1)
2,3,7	1	3	
2,7,4	3	7	2(4-2)
3,4,5	2	5	(4-5)
3,5,7	2	5	(3-5)
3,6,4	1	3	
3,6,5	1	3	
3,7,4	1	3	
4,6,7	1	3	
4,7,5	2	6	
2,5,7	1	2	(2-5)
Totals	29	74	10
	29	74	10

FIG. 1

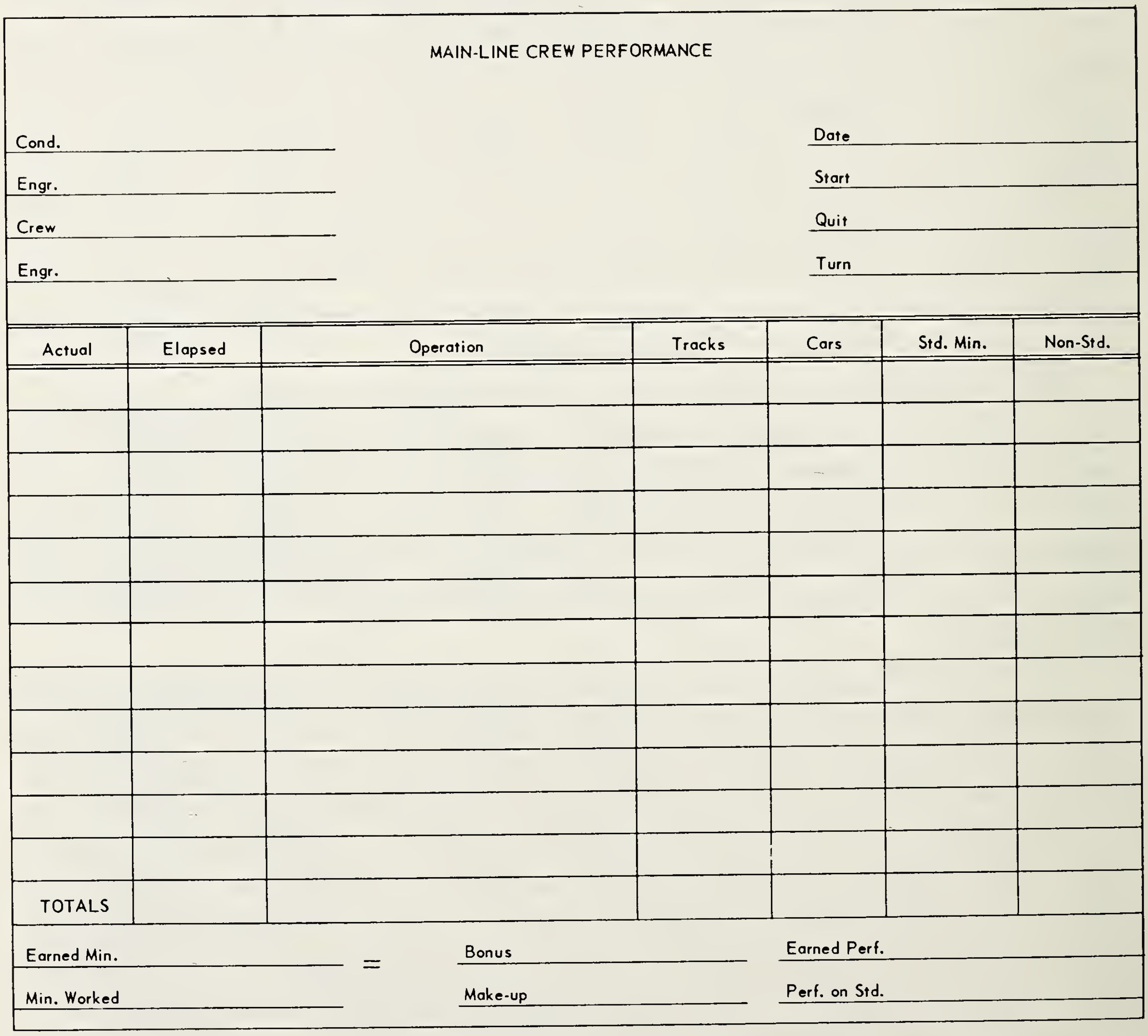
a "tonnage-handled basis," the URC ranks among the top 15 railroads in the country. Its operations are divided into two broad classifications: 1) main-line operations and 2) switching operations. These classifications also reflect the nature of the work to be performed by the crews. As previously explained, the main-line work, involving 30 to 40 crews per day, consists of picking up cars at interchange yards with trunk lines connecting at other places on the railroad. For some customers delivery merely means setting off "a cut of cars" at a plant or public siding. In the large majority of plants, however, whole train loads of cars are placed into inbound storage yards and the customer will, at some later date, notify the URC when particular cars are required for unloading. Regular main-line movement resumes when the empty cars or outbound loads are picked up in the customers' outbound yard and again assembled into trains for delivery to trunk lines or other customers on the railroad. Switching, as opposed to main-line work, covers all car movements within a plant.

In order to schedule main-line freight trains, it is necessary to know first what cars or commodities are at the various interchange or plant areas and where these cars or commodities are bound. Having this information, the train movement director's office issues the various orders required to effect the deliveries or moves. When the staff at the office reports for work at the start of the turn, they will find a list of locomotives of various sizes and capabilities available at approximately 21 different starting points. In addition, they will also know how many crews have been hired for that particular turn to operate the locomotives and where these crews will report for work. With this information, specific assignments of work to be performed by each crew during part or all of the turn are drawn up.

The train movement director has a wide variety of possible assignments to choose from and also a large number of restrictions on his choice in the same manner as the production control department has in a manufacturing organization. As an operating problem, then, the solution of linear programming applications to the scheduling of crews must provide the scheduling staff with a set of decision-making rules which will enable the highest operating efficiency to be obtained.

In the specific application of linear programming the *assignment method* was chosen as the best for the scheduling of the crews. This is fast, and because speed is the essence of good scheduling in this business, its applicability is beyond doubt. Although cost is an important consideration, it is assumed that by scheduling crews to the utmost number of pickup points without taking a chance that pickup is either late or must be made with overtime work and pay, costs will automatically be reduced (that is, as long as scheduled stopovers can be made prior to sending off a crew). Thus, everything must be scheduled prior to start of the turn. This seems simpler at superficial observation than it is. It must be stated, therefore, that the various companies, whether Westinghouse, J & L Steel, Bethlehem Steel, U. S. Steel, or Alcoa, using the services of the Union Railroad Company, do not usually tell a day or so ahead that they will have a carload to pick up; they usually call in and want a pickup within an hour or even faster. Thus, the scheduler often learns too late about a pickup and, when a crew has already left, it is too late for them to make the pickup. They are already en route.

According to the proposition of the young industrial engineer, in the "assignment method" a matrix is set up with the various crew members listed in the column under the word "crew." The rows opposite each crew's number are the performance ratings for that crew on the different jobs. On the main-line movements there is usually a certain pattern of operations set up for each job. In other words, job A will usually involve the same operations day after day and the same applies to jobs B, C, etc. This may consist of traveling from the same starting point every day to several different points and hauling approximately the same number of cars each day. These particular jobs may be thought of as being somewhat repetitious. At one time or another each of the



MAIN-LINE CREW PERFORMANCE

Cond. ____________________ Date ____________________
Engr. ____________________ Start ____________________
Crew ____________________ Quit ____________________
Engr. ____________________ Turn ____________________

Actual	Elapsed	Operation	Tracks	Cars	Std. Min.	Non-Std.
TOTALS						

Earned Min. ____________________ = Bonus ____________________ Earned Perf. ____________________
Min. Worked ____________________ Make-up ____________________ Perf. on Std. ____________________

FIG. 2

crews has worked on these jobs and performance ratings have been set up for these crews on each of these jobs. These performance ratings have been determined by comparing the crew's actual work time with standard times that have been set up for various operations. This calculation is done on a main-line crew performance sheet (see Fig. 2) on a daily basis. These performances are then kept on a calculated crew performance sheet (see Fig. 3) for each crew's performance on the various main-line jobs.

Whenever the train movement director (a job which combines routing, scheduling, and dispatching work in the manufacturing sense) gets the information each turn as to what jobs are to be performed and which crews are

CALCULATED CREW PERFORMANCE

Date	Crew	Start	Location	Eng.	Engineer	Conductor	Performance Percentage

Fig. 3

available, this information is set up in matrix form and each crew is assigned to the job which will give the highest total performance efficiency for that turn. On any one turn the available jobs to be performed may exceed the number of crews available, be less than the crews available, or be equal to the crews available. As an illustration of how the *assignment method* is applied to crew scheduling, it will be assumed that there are ten jobs to be performed and ten crews to perform the work (this is of course not authentic, but it can illustrate the method in question).

Initial matrix A, Fig. 4, is set up listing each crew number available on that turn and the performance that has been recorded for each crew's efficiency on each of the jobs to be performed.

Crew	A	B	C	D	E	F	G	H	I	J
1	90	75	60	80	75	70	55	60	75	65
5	65	55	80	60	65	80	90	65	85	70
8	75	75	60	75	75	75	80	80	60	65
9	60	70	75	70	50	55	75	75	80	80
10	85	95	65	70	60	80	70	70	85	65
17	85	80	80	85	85	75	80	80	85	75
24	70	75	70	75	80	70	75	65	70	80
25	75	55	85	70	65	90	60	75	70	75
26	80	85	50	85	90	75	80	60	65	70
34	60	60	65	80	70	80	65	85	60	80

FIG. 4. Matrix A.

1. Inspect matrix A and find the highest performance rating. In this illustration crew 10 has 95% performance on job B.

2. Matrix B will now be constructed. To obtain matrix B, Fig. 5, subtract each number in matrix A from 95. Thus, crew 5 has an 80% performance on job C. That same position, 5 C, in matrix B will be 15 (95 − 80 = 15).

Crew	A	B	C	D	E	F	G	H	I	J	R
1	5	20	35	15	20	25	40	35	20	30	5
5	30	40	15	35	30	15	5	30	10	25	5
8	20	20	35	20	20	20	15	15	35	30	15
9	35	25	20	25	45	40	20	20	15	15	15
10	10	0	30	25	35	15	25	25	10	30	0
17	10	15	15	10	10	20	15	15	10	20	10
24	25	20	25	20	15	25	20	30	25	15	15
25	20	40	10	25	30	5	35	20	25	20	5
26	15	10	45	10	5	20	15	35	30	25	5
34	35	35	30	15	25	15	30	10	35	15	10
K	5	0	10	10	5	5	5	10	10	15	

$\Sigma R = 85$

$\Sigma K = 75$

FIG. 5. Matrix B.

3. After the last number in the crew column write the letter K. After the last letter in the job row write the letter R. From each column and from each row the lowest number must be selected. For the rows, the lowest number

would be placed in column K. For the columns, the lowest number would be placed in row R.

4. a. Add the numbers in column R and write that sum down on the side.

b. Add the numbers in line K and write that sum down. Thus, $\Sigma R = 85$ and $\Sigma K = 75$.

5. a. Inspect ΣR and ΣK and determine which is the larger number. If ΣR is larger, we will work with rows; if, however, ΣK is larger, we will work with columns.

b. Now we construct matrix C, Fig. 6, and subtract each number in column R from every number in that row.

	✓	✓			✓	✓	✓	✓			
Crew	A	B	C	D	E	F	G	H	I	J	
1	0	15	30	10	15	20	35	30	15	25	
5	25	35	10	30	25	10	0	25	5	20	
8	5	5	20	5	5	10	0	0	20	15	
9	20	10	5	10	30	25	5	5	0	0	✓
10	10	0	30	25	35	15	25	25	10	30	
17	0	5	5	0	0	10	5	5	0	10	✓
24	10	5	10	5	0	10	5	15	10	0	✓
25	15	35	5	20	25	0	30	15	20	15	
26	10	5	40	5	0	15	10	30	15	20	
34	25	25	20	5	10	5	20	0	25	5	

Fig. 6. Matrix C.

c. We draw the minimum number of lines through the columns and rows so that every zero (0) has a line running through it.

6. Now the problem at hand is so arranged that a solution can be found. The most efficient solution is found when there is a zero in each row for each crew. One should keep in mind that only one crew can do one job. Therefore, each crew must have a zero different from all the others.

By inspecting matrix C, we can determine if there is a separate zero (0) for each employee in the job column. Upon analyzing matrix C, it will be noted that there is no zero in column C and therefore no crew has been assigned this job yet. Thus, the final solution has apparently not been reached.

a. Matrix D-1, Fig. 7, will have to be constructed. From those numbers

Crew	A	B	C	D	E	F	G	H	I	J	
1			25	5					10	20	
5			5	25					0	15	
8			15	0					15	10	
9											
10			25	20					5	25	
17											
24											
25			0	15					15	10	
26			35	0					10	15	
34			15	0					20	0	

Fig. 7. Matrix D-1.

in matrix C not having a line running through them, the lowest number must be selected. Based on the illustration, this lowest number is 5.

b. By subtracting that lowest number—that is, 5—from all other numbers which do not have a line running through them we get matrix D-1.

c. By adding the same number in this example, 5, to those numbers where the lines intersect in matrix C we get the matrix D-2, Fig.8.

Crew	A	B	C	D	E	F	G	H	I	J
1			25	5					10	20
5			5	25					0	15
8			15	0					15	10
9	25	15			35	30	10	10		
10			25	20					5	25
17	5	10			5	15	10	10		
24	15	10			5	15	10	20		
25			0	15					15	10
26			35	0					10	15
34			15	0					20	0

FIG. 8. Matrix D-2.

d. By completing Matrix D-2 by writing in all other numbers in matrix C unchanged (see matrix D-3, Fig. 9,) slowly but surely we approach the solution. Obviously, the solution would be a bit time consuming if the paper-and-pencil method were to be used to perform these manipulations. But, of course, the idea is predicated upon the assumption that in the not too distant future a small but high-speed computer will be obtainable on the market which will be capable of handling the time-consuming part of this procedure. With this possibility in mind, the various comparisons would take only a few minutes.

		✓	✓		✓			✓	✓	✓	✓
	Crew	A	B	C	D	E	F	G	H	I	J
	1	0	15	25	5	15	20	35	30	10	20
	5	25	35	5	25	25	10	0	25	15	0
	8	5	5	15	0	5	10	0	0	15	10
	9	25	15	5	10	35	30	10	10	0	0
	10	10	0	25	20	35	15	25	25	5	25
	17	5	10	5	0	5	15	10	10	0	10
	24	15	10	10	5	5	15	10	20	10	0
✓	25	15	35	0	15	25	0	30	15	15	10
✓	26	10	5	35	0	0	15	10	30	10	15
	34	25	25	15	0	10	5	20	0	20	0

FIG. 9. Matrix D-3.

e. Draw the minimum number of lines through the columns and rows so that all zeros (0) have a line running through them (see matrix D-3).

f. Inspect matrix D-3 and determine if there is one zero for each crew.

In this illustration jobs C and F are both assigned to crew 25. Thus, there is still something to do to resolve the problem at hand, because a job can be assigned to one crew only.

7. a. Construct matrix E, Fig. 10, exactly the same as matrix D-3 was set up.

Crew	A	B	C	D	E	F	G	H	I	J
1	⓪	15	20	5	10	15	35	30	10	20
5	25	35	0	25	20	5	⓪	25	0	15
8	5	5	10	0	0	5	0	⓪	15	10
9	25	15	0	10	30	25	10	10	⓪	0
10	10	⓪	20	20	30	10	25	25	5	25
17	5	10	⓪	0	0	10	10	10	0	10
24	15	10	5	5	0	10	10	20	10	⓪
25	20	40	0	20	25	⓪	35	20	20	15
26	15	10	35	5	⓪	15	15	35	15	20
34	25	25	10	⓪	5	0	20	0	20	0

FIG. 10. Matrix E.

b. By inspecting matrix E, it can be seen that there is a separate zero for each crew. This mathematically is the best solution.

c. In this illustration the average crew performance per crew by the optimum solution is 85.5%. This would be the assignment of crews to jobs for this particular turn.[12]

8. If there were several crews which could have been assigned to different jobs under the optimum solution and the total efficiency would have remained the same, then the train movement director's judgment (as to assignments) would always prevail.

The system thus suggested will give a fast and effective arrangement of crew assignments provided it is performed via a high-speed computer. A further advantage of the program would be that the number of staff now working in the train movement director's office would no longer be needed.

Questions. Ordinarily the case selected requires the student to analyze the problem to discover what is wrong with present practices. This case illustrates the opposite situation. The company has solved (that is, it has a feasible suggestion for solving) the scheduling problem with the help of a linear programming method of operations research. Thus, the task of the student is merely to criticize the suggested method on the one hand and to apply this scheduling method to the scheduling of factory operations (instead of railroad operations), on the other hand.

1. Would you accept the linear programming method as a solution to the problem of scheduling crew assignments if you were in authoritative position

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[12] Now the interested readers should turn to Appendix G to understand *why* we reshuffle rows and columns and read about the mathematical foundations for changing either a row of numbers or a column of numbers. Specific reference is made to the section dealing with matrix manipulations (p. 837).

at the Union Railroad Company? Do you have any misgivings? If so, list your objections.

2. How would you have solved the crew scheduling problem without the use of linear programming? Could any one of the Gantt charting techniques easily be enlisted to replace the mathematical approach?

3. Discuss linear programming in the railroading business, and contrast it with production situations in order to see the different considerations which must be made to make it succeed.

4. What kind of mathematical method—besides linear programming—would lend itself to the solution of the same kind of scheduling problems?

5. Could you improve the method of linear programming to be employed by the Union Railroad Company? Explain your suggestions.

15-2. BASIC CHEMICALS, INC.[13]

A subsidiary of a large steel company, Basic Chemicals, Inc., is charged with the duty of determining 1) the chemical composite of ore mined for the parent organization in different parts of the world and 2) subsequently, the percentage of ore ingredients to be charged into a blast furnace to attain desired ingot quality. In order to make a ton of ingot steel, 2½ to 3 tons of raw material is needed, including iron ore, limestone, coke, and scrap iron. The cost of the ingot depends on the qualitative requirements and the quality and cost of available raw materials. Some materials are scarce, depending on the abundance or scarcity of the ore deposit in question.

Currently, Basic Chemicals, Inc. is experimenting with Venezuelan, Canadian, Labradorian, and Congolese iron ores to determine the percentage ratio of the various iron ores in the blast furnace charge to attain given quality of hot metal (ingot) at minimum cost. The quality of hot metal can be compared to a good spaghetti sauce. Depending on the percentage of the various spices, the sauce will taste differently. A bit more salt content might ruin the excellent taste. A bit more than the required manganese or phosphorus content in a blast-furnace charge might give an undesirable ingot quality. Consequently, the sum total of all blast furnace charge must, in the final analysis, give the quality which is desired. Thus, it is essential to determine in advance for instance, the percentage of Venezuelan, Congolese, Labradorian, Canadian, etc. ores to be charged into the blast furnace to come up with a quality containing $x\%$ of manganese, $y\%$ of phosphorus, $z\%$ of carbon, etc.

Iron smelting takes place in the blast furnace. The cylindrical structure is charged with the various ingredients of ore (possibly four or five different ores in different ratios), limestone, coke, and scrap metal on the top in the same manner as an old-fashioned stove is fed with fuel. Air is forced through the charge to supply oxygen. During the burning process, the ore is reduced to metal, which settles to the bottom of the furnace, while the impurities react with the limestone and float on top of the iron in the form of slag. The smelting process takes anywhere from a half day to a day depending on the type of furnace and the air supply and pressure. When the "cast" is finished, a plugged hole at the bottom of the blast furnace is opened up and the red-hot molten metal runs in a riverlike manner into predetermined containers for further fabricating purposes. The liquid hot metal must be of a predetermined quality and be produced at the least cost.

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[13] For the mathematical computations I am indebted to senior engineer and industrial engineering supervisor Charles E. Miller, of a well-known steel company. The computations are a part of an unpublished master's thesis; the author was the thesis advisor. The original idea is based, however, on Tibor Fábián's, "Application of Linear Programming to Steel Production Planning," *Operations Research*, vol. 3, p. 565 (abstract), 1955.

The production of a cast (a batch of hot metal) tends to cost different amounts of money depending on the price of the ore used in the charge, the cost of transportation of the ore from the ore mine to the blast furnace site, and the quantity of the ore in the charge. Out of the iron ore needed (say, 168 pounds) 25% might be Congolese, 30% Canadian, and 45% Venezuelan ore, that is $42+50.4+75.6=168$ pounds. The total cost of the charge depends on the cost per ton of given ore. Obviously, the cheaper the smelting process, the lower is the cost of making fabricated steel products.

In the past, steel companies experimented with different combinations of ore, just as housewives experiment with pouring salt and tasting the results until the required quality is attained. When the chemical composition of the ore changes, the experimentation must be started from scratch. And, of course, the chemical composition of the ore depends on the geological conditions under which the ore was formed in different parts of the world. Basic Chemicals, Inc., however, developed a method of operations research which, through a chemical analysis of samples of the ore taken out of a cargo, enables determination of the charge (that is, the ratio of ore ingredients to attain the predetermined hot-metal quality) without the necessity of experimentation. There is a tremendous saving in this method.

A chemical analysis and other requirements of a specific batch (cast) is given in the table on p. 740. According to the chemical analysis of sample ores from Venezuela (ore 1), Canada (ore 2), Labrador (ore 3), and the Congo (ore 4), the company uses a mathematical method to be explained later to determine the ore ingredients of a blast furnace charge to attain the following chemical qualities: 1) manganese must be equal to 0.70%; phosphorus must be equal to or less than 0.15%; sulfur must be equal to or less than 0.04%. 2) Because of the scarcity of supply, Venezuelan ore should not constitute more than 20% of the hot metal.

To determine the costwise best ore mixture, logically the most expensive ore should have the least percentage in the mixture of 100% (that is, the sum total of all ores used), provided that the mixture (the blast furnace charge) meets the quality requirements on the one hand and not more than

	Ore 1	Ore 2	Ore 3	Ore 4
Chemical analysis of ore, per cent:				
Iron	58.80	52.10	49.03	49.40
Phosphorus	0.12	0.07	0.06	0.06
Silicon	.41	10.10	8.86	8.88
Manganese	——	0.41	0.88	0.84
Alumina	.86	.87	1.39	1.98
Lime	.09	.22	0.12	0.09
Magnesia	.09	.17	0.11	0.09
Sulfur	0.03	0.03	0.01	0.01
Moisture	7.11	8.69	11.56	12.08
Hot-metal analysis,* per cent:				
Iron	95.35	94.31	93.72	93.65
Carbon	3.35	3.68	3.72	3.90
Silicon	1.00	1.30	1.15	1.12
Sulfur	0.10	0.03	0.03	0.03
Phosphorus	0.19	0.13	0.12	0.11
Manganese	——	0.55	1.26	1.19
Metal requirements, pounds per net ton of hot metal	3519	4139	4365	4336
Coke requirements, pounds per net ton of hot metal	1375	1711	1708	1725
Flux requirements, pounds per net ton of hot metal:				
Limestone	142	713	701	732
Dolomite	37	208	216	232
Slag, pounds per net ton of hot metal	222	1033	1024	1069
Cost, dollars per net ton of hot metal	35.22	38.39	38.28	38.58

* Components, in per cent, under the assumption of chemical changes known to occur during smelting.

20% Venezuelan ore is used, on the other hand. In a Simplex (a specific form of linear programming) this is expressed as

$$O_1+O_2+O_3+O_4=1.00$$

where O represents the ore and subscripts 1, 2, 3, 4 represent the respective ores. In order to be able to experiment (on paper) with different combinations, U_1 and U_2 will represent unknowns. Accordingly,

$$O_1+O_2+O_3+O_4+U_1=1.00$$

Since the mixture is subject to the above restrictions, such as certain percentages of manganese, phosphorus and sulfur that must be contained in the hot metal, they must be illustrated as follows:

Manganese .... $0.00O_1+0.55O_2+1.26O_3+1.19O_4=0.70$
Phosphorus .... $0.19O_1+0.13O_2+0.12O_3+0.11O_4\leqq 0.15$
Sulfur .... $0.10O_1+0.03O_2+0.03O_3+0.03O_4\leqq 0.04$
20% or less Venezuelan ore .... $O_1\leqq 0.20$

In order to solve the problem, U_2 must be added to the first equation: $0.00O_1+0.55O_2+1.26O_3+1.19O_4+U_2=0.70$ and to eliminate inequalities, x, y, and z are needed in inequalities 2, 3 and 4. Thus,

$$0.19O_1+0.13O_2+0.12O_3+0.11O_3+x=0.15$$
$$0.10O_1+0.03O_2+0.03O_3+0.03O_4+y=0.04$$
$$O_1+z=0.20$$

In order to minimize costs and at the same time to meet all other requirements, such as manganese, phosphorus, and sulfur content in addition to the 20% limitation on Venezuelan ore, the following equation must be solved:

$$-35.22O_1-38.39O_2-38.28O_3-38.58O_4 \\ -MU_1-MU_2-Ox-Oy-Oz=\text{maximum}$$

The solution is shown in Figs. 1 thru 4. In Fig. 4 the constant column indicates values of 0.69 for O_2, 0.25 for O_3, and 0.06 for O_1, whereas no value is shown for O_4. Accordingly, the blast furnace should be charged with the above percentages of the various ores. Evidently, Congolese ore should not be used at all.

Objective Row				-35.22	-38.39	-38.28	-38.58	-M	-M	0	0	0	Check Column
Variable Row				O_1	O_2	O_3	O_4	U_1	U_2	X	Y	Z	
I	-M	U_1	1.00	1	1	1	1	1	0	0	0	0	6.00
II	-M	U_2	0.70	0	0.55	1.26	1.19	0	1	0	0	0	4.70
III	0	X	.15	0.19	.13	0.12	0.11	0	0	1	0	0	1.70
IV	0	Y	.04	0.10	.03	0.03	0.03	0	0	0	1	0	1.23
V	0	Z	0.20	1	0	0	0	0	0	0	0	1	2.20
Index Row			-1.70M	-1M 35.22	-1.55M 38.39	-2.26M 38.28	-2.19M 38.58	0	0	0	0	0	-8.70M 150.47

FIG. 1. First simplex matrix.

A careful observation will reveal that this ore mix meets the quality requirements in that manganese content is equal to 0.70% (because when the ore percentages are multiplied by the amount of manganese in each ore, the total manganese content comes out 0.6945, that is, 0.70%)

Objective Row				-35.22	-38.39	-38.28	-38.58	-M	-M	0	0	0	Check Column
Variable Row				O_1	O_2	O_3	O_4	U_1	U_2	X	Y	Z	
I	-M	U_1	0.45	1	0.56	0	0.06	1	-0.79	0	0	0	2.28
II	-38.28	O_3	.55	0	.44	1	0.94	0	.79	0	0	0	3.72
III	0	X	.09	0.19	.07	0	0	0	-.10	1	0	0	1.25
IV	0	Y	.02	0.10	.02	0	0	0	-0.02	0	1	0	1.12
V	0	Z	0.20	1	0	0	0	0	0	0	0	1	2.20
Index Row			-0.45M -30.38	- 1M 35.22	-0.56M 21.68	0	-0.05M 2.43	0	1.79M -30.38	0	0	0	-.27M -1.43

Fig. 2. Second simplex matrix.

Objective Row				-35.22	-38.39	-38.28	-38.58	-M	-M	0	0	0	Check Column
Variable Row				O_1	O_2	O_3	O_4	U_1	U_2	X	Y	Z	
I	-M	U_1	0.25	0	0.36	0	0.06	1	-0.59	0	-10	0	-8.92
II	-38.28	O_3	.55	0	.44	1	0.94	0	.79	0	0	0	3.72
III	0	X	.06	0	.04	0	0	0	-.05	1	-1.90	0	-0.85
IV	-35.22	O_1	0.20	1	.20	0	0	0	-.20	0	0.10	0	11.20
V	0	Z	0	0	-0.20	0	0	0	-0.20	0	-10	1	-9.00
Index Row			-0.25M -37.42	0	-0.36M 14.64	0	-0.05M 2.43	0	1.59M -23.34	0	10M -352.20	0	10.93M -395.89

Fig. 3. Third simplex matrix.

Objective Row				-35.22	-38.39	-38.28	-38.58	-M	-M	0	0	0	Check Column
Variable Row				O_1	O_2	O_3	O_4	U_1	U_2	X	Y	Z	
I	-38.39	O_2	0.69	0	1	0	0.17	2.78	-1.64	0	-27.77	0	-24.77
II	-38.28	O_3	.25	0	0	1	.87	-1.22	1.51	0	12.22	0	14.63
III	0	X	.03	0	0	0	-.01	-0.10	0	1	-0.78	0	0.14
IV	-35.22	O_1	.06	1	0	0	-.03	-.56	0.13	0	15.56	0	16.16
V	0	Z	0.14	0	0	0	0.03	0.56	-0.13	0	-15.56	1	-13.96
Index Row			-47.60	0	0	0	0	M -40.70	M 0.67	0	54.78	0	2M -32.85

FIG. 4. Fourth simplex matrix.

Ore	Percentage (*A*)	Manganese Content (*B*) in Pct.	Manganese (*A*×*B*)
1	6	——	0.0000
2	69	0.55	0.3795
3	25	1.26	0.3150
			0.6945

The same applies to phosphorus, which cannot exceed 0.15% in the charge, and to sulfur content, which cannot exceed 0.04%. Thus,

Ore	Percentage (*A*)	Phosphorus Content (*B*)	Sulfur Content (*C*)	Phosphorus (*A*×*B*)	Sulfur (*A*×*C*)
1	6	0.19	0.10	0.0114	0.0060
2	69	0.13	0.03	0.897	0.0207
3	25	0.12	0.03	0.0300	0.0075
				0.1311	0.0342

It should also be noted that the scarce Venezuelan ore (not to exceed 20% of the total charge of the blast furnace) represents only 6% of the blast furnace charge.

The cost thus incurred is the minimum, and any other mixture would cost more. Total cost based on above ratio of ingredients is:

Ore	Percentage (A)	Cost (\$) per Net Ton Hot Metal (B)	Cost ($A \times B$)
1	6	\$35.22	\$ 2.1132
2	69	\$38.39	\$26.4891
3	25	\$38.28	\$ 9.5700
		Total cost . . .	\$38.1723

Basic Chemicals, Inc. proposed to Amalgamated Iron and Steel, Inc., the parent organization, a system whereby samples of newly mined ore at the time of loading into barges are classified and sent via air cargo to Basic Chemicals, Inc. for analysis for the ultimate purpose of determining the charge ratio of different ingredients in light of batch quality (cast or ingot quality) requirements by the various steel producing units. According to this suggestion, while the cargo of ore travels from, say, a Canadian port, the ore analysis is made and by the time the ore arrives at destination, a precise production plan is designed for that particular shipment. Basic Chemicals, Inc. prefers shipment of the ore samples, rather than chemical results, because the company has excellent facilities for the analysis; if done at the mining site by domestic metallurgical engineers, the accuracy of the analysis is doubtful as far as Basic Chemicals is concerned and the results of the computations can conceivably be distorted.

The experimental blast furnace, a sort of little sister to the huge blast furnaces, at the disposal of Basic Chemicals Incorporated is one of the best in the country and will, particularly in combination with operations research methods, yield new knowledge of iron smelting. Furthermore the company has recently obtained the latest IBM digital computer. Thus, even if 20 to 30 different ores might have to be mixed with different cost and supply restrictions, when the hot metal requirements (as expressed in quality specifications) and other considerations are multitudinous, the computation can be accomplished within a few hours.

Of course, to avoid costly ore shipments from the mining site (that is, shipment of ore that contains too much impurities), it is assumed that each mining site will, prior to shipping the ore, refine the crude ore. The crude ore is a coarse-grained specular hematite containing only a little over 25 to 30% of iron. In concentrators, the crude ore can be stripped of extraneous materials so that when it is loaded into barges, the ore content is already 60 to 70% of iron. Thus, the cost of transportation can be greatly reduced. With the concentration of the iron content, the other chemical composites are also concentrated. At any rate, at Basic Chemicals, Inc., on the basis of the chemical analysis of samples of either crude or refined ore the blast furnace charging plan would be developed.

The suggestion amounts to the centralization of the production planning function in the hands of the Basic Chemicals, Inc. The various blast furnaces would always be directed from a central location, at least as far as the charging plan would be concerned. The various steel-producing units would inform Basic Chemicals, Inc. about the quantity and quality of the hot-metal content; BCI, in turn, would compare the various ore shipments and shipment destinations (in light of the chemical content) with one another so that at the time of arrival for every cargo a precise plan would be established. The net result, according to the statements of BCI's president, would be 1) an orderly disposal of ore shipments, 2) improvement of the quality of iron, and subsequently, 3) improvement of the quality of fabricated steel products. But above all, 4) a sizable reduction in the cost of production of different qualities of iron would be attained. A fringe benefit, BCI's president claims, is that 5) a precise knowledge about the costs of production would exist. This was not available until now, except after the metal was already cast.

Questions. The proposal made by Basic Chemicals, Inc. to Amalgamated Iron and Steel Incorporated is appealing and is debated at various management levels. Executives believe that the operations research method has not been clearly enough explained and requires a more precise explanation.

1. Develop a precise but layman's explanation of the method of arriving at the percentage ratio of various ingredients. This will require an oversimplified explanation of the *simplex method* of operations research (linear programming).

2. Management of Amalgamated wants to see the precise formulas (models), which could be programmed into the computer and would, in turn, answer any ore mix question on the basis of raw information: iron content, other chemical element content, quality requirements, and price and scarcity restrictions. Indicate, therefore, how the computer should be programmed.

3. Is the suggestion made by Basic Chemicals, Inc. to Amalgamated, Inc. a feasible as well as a good proposition?

4. Check the method (used in the operations research approach) and indicate the suitability of the method for the ore mix problem (that is, this function is equivalent to the routing function in other industries).

15-3. THE LINDSTROM CORPORATION

Located in a four-story building in Chicago's south side, the Lindstrom Corporation manufactures a large variety of farm equipment and implements. Although the company's plant capacity was rated to be approximately 10,000 units of a "normal product mix," company output has not yet reached its rated capacity. As a matter of fact, the highest monthly output so far was somewhat less than 8000 units, and this despite the fact that demand for the company's products has always exceeded the plant's rated capacity. In view of the cyclical nature of the farm implement business, however, the company did not contemplate an expansion. Although production went on the year around, sales were down practically to nothing during the winter months. By March, however, sales were in high gear.

Although the company always experienced considerable difficulty with scheduling, it only recently became apparent that something drastic should be done about the effectiveness of scheduling—or, more precisely, about the rescheduling—of the flow of nearly 700 parts through approximately 24 machine groups. Caused by frequent changes in production schedules resulting from unexpected shifts in farm needs, it became increasingly more difficult to reschedule departmental workloads with the help of the Schedugraph currently in use. When one change was made, a series of corresponding adjustments had to be made on dozens of charts. The net result of revamping schedules over and over again was that some machine groups remained relatively idle (that is, were not utilized every minute of the day), whereas other machine groups were overloaded with work to the extent that overtime work became necessary.

To better understand the nature of the difficulty the Lindstrom Corporation experienced, one ought to analyze why the demand for specific farm implements was unpredictable. Lindstrom farm machinery and implements are used for different agricultural purposes. As farmers alternate their crops year after year, the need for the appropriate farm implements will alternate correspondingly. What crops the farmer will grow each year is impossible to predict. Yet, when the farmer needs an implement, he needs it not next month, but immediately and wants to buy it. In order to meet demand, dealers must have in stock at least one unit of each implement or piece of equipment. There are many different Lindstrom products and it is impossible to know which implement will be in demand. Therefore, dealers do not know what to order and the manufacturer is at a loss to plan production schedules. Production lead time varies from 2 to 3 months, and it is difficult to replenish dealer inventories unless schedules are changed in midstream. Even then, delays in shipment to dealers might still mean that the customer finally ends up with some other manufacturer's product.

Thus, as a given item appears to move faster than others, the scheduling group must immediately readjust production schedules to assure availability of all the parts which ultimately go into these fast-moving items. Specifically, 50% of all farm implements contain interchangeable parts which are common to all output units. The necessity, however, of making more of an assembled item means that more of a given component must be manufactured. If the assembly of implement A was foreseen but it is discovered that B is selling, it is possible to change assembly schedules immediately; but to make the parts composing B available will create difficulty. If we assume that both items A and B require gusset blocks but only five gusset blocks are needed in A, whereas ten gusset blocks make up B, the change in the assembly schedule will have to be accompanied by schedule changes in gusset block manufacturing. Thus, certain machine groups will be tied up longer than originally anticipated and will cause dozens of changes in departmental work load and machine load distribution. In other words, the whole machine shop schedule must be revamped.

The volume of paper work caused by such frequent changes became so burdensome that, to avoid constant changes, it often became necessary to issue shop orders over the telephone without sending down to the shop the appropriate route sheets, job cards, and departmental programs as outlined in the production control office, etc. After the fourth or fifth schedule change, production foremen no longer paid attention to the instructions received from production control but went on with their own schedules. The setups were so frequent and piece-rate earnings so poor that foremen had to look out for the welfare of their own subordinates. Machine shop workers were skilled machine operators, and foremen did not want to lose any of their experienced men because it was difficult to replace them.

In the final analysis, the company made the same products year in and year out; and when a switch was necessary, the men could switch without lengthy instructions. They went to the toolroom, picked up the appropriate jigs and fixtures, set up their own machines, etc. At any rate, frequent changes in production runs made it impossible for these men to make any money on the production of any item owing to the fact that the starting up and stopping of a run in midstream virtually deprived workers of their legitimate piece-rate earnings, which tended to rise sharply with higher production runs.

Farmers were not the same kind of buyers as industrial customers. They purchased haphazardly as they found it convenient, or necessary, to employ farm implements to take in the crop. As bad weather, for instance, approached and the farmer noticed it coming, he hurried to a downtown dealer to acquire a given farm implement to enable him to harvest his crop. When Lindstrom trademarked items were not available for sale, another product capable of doing essentially the same work was purchased. Dealers, however, expressedly stated that farmers preferred Lindstrom products because of their durability, reliability, and otherwise high quality.

Dealers had Lindstrom products on consignment. When they were sold, the manufacturer replaced the item as fast as its production could catch up with demand. If forecasting had properly anticipated demand, replacement was quick; if, however, frequent switchovers were required, production losses and the impossibility of assembling the item in question because of the inavailability of *all* component parts caused lengthy delays.

To remedy the situation as far as production scheduling was concerned, one of the worthwhile suggestions was to use an electronic computer and operations research models for the purposes of scheduling. With a computer the reschedules could be made quickly and all paper work could be sent down to foremen always in time.

A high-speed computer was available during 2 hours per day for this purpose. The main requirements of scheduling with the computer are that economic lot sizes and the frequency of production runs for each part will have to be predetermined—only the specific day and time of the day when a lot is to run, vary with the changes in sales conditions. Raw material inventory levels had to be established in terms of maximum and minimum inventory levels. The inventory level would have to be low enough to prevent overstocking of going parts, yet adequate to keep up production (assembly) long enough without running out of parts regardless of a shift to another product. Also, transit times of the various parts between machine groups had to be established in order to set the inventory level so that the frequency of production was duly considered.

The current difficulty resulted from the fact that a switchover from the assembly of one item (that is, putting standard parts together in different combination) eventually depleted the availability of a given part faster than anticipated. To make up the shortage in parts, the shop schedules had to be revised to accommodate the change which was necessitated by the conversion from making the item more in demand rather than the one less sought after. The result was that some machine groups were severely overburdened and some others became substantially underloaded. The cost problem was evident: 1) overtime work on the overloaded machines meant higher labor cost; 2) underloading certain machine groups not only raised the overhead cost but represented a permanent loss of machine time in the sense that machines which stood idle were, in a subsequent period, probably urgently needed. It was like a river in springtime. When too much water must come down, there is a flood; whereas if the water would come down from the mountains in piecemeal (regularly), the river bed could easily carry down all the water. It should be remembered that original production plans utilized all equipment equitably and the work-load distribution between departments was well planned. The trouble originated from the necessity of making one change in schedules after the other. Frequent adjustments of schedules made the rescheduling work so confusing that equipment capacities and production flow got so mixed up that it was nearly impossible to bring schedules back to normal.

Different operation sequences and machine performance times on different parts and operations have evidently created severe imbalance in departmental work loads. In a subsequent period, of course, it was conceivable that a given machine group now idle would have to be overloaded as a result of the need for parts and of operations which required the services of those machines. An unfortunate concomitant of sudden changes was a substantial reduction of the plant's normal capacity from 10,000 units of a normal product mix to 6000 units. This was even less than the already established output capacity of 8000 units per month.

The company's problem can be clearly seen. The aim of a new automated production control system is to raise plant output to 10,000 units, supply the market all the time with the needed goods, yet operate plant facilities at their utmost efficiency. The automated production control work might be expensive in view of the fact that 2 hours of computer time needed per day to carry out production control work might cost considerably more to the company than the cost of running the present production control department. It appears probable, however, that better schedules and higher sales will more than offset the expenses thus incurred. The assumption is that schedules as well as reschedules will consider all important factors and at the same time will always be updated. Foremen will always be notified sufficiently ahead of time what they will have to make so that they can make appropriate arrangements.

No special difficulty is anticipated because the production control department knows the quantity of each part to be made and the reject rate as well as all other factors necessary to maintain high production levels with a normal product mix. Records of the last 5 years can reveal, at least statistically, the number of times each part has been manufactured in the past. Thus, probable future requirements can be predicted. Also, economic lot quantities based on cost, cost of storage, ratio of setup to running time, size of the runs, etc. are available.

It appears to company management that everything necessary to develop operations research models and to program a computer is available. It should also be remembered that most decisions seem to be routine in a sense that if the information available is arranged in a meaningful manner, the production decision is relatively simple. The market developments are, however, always unknown elements. At the time sales trends become known, the previous production program is well underway and changes to be made must be effectuated when production is in midstream.

Management expects, from computer control and operations research work, quick and precise decisions on the one hand and fast preparation of production papers on the other hand. The computer will likely be able to furnish, for instance, the purchasing department with accurate information about the availability of materials in storerooms and in the process of production. As a matter of fact, it is expected of the computer that it will print out purchase orders and quantities automatically as certain minimum levels are reached.

The Lindstrom Corporation has assigned the preliminary investigation to a staff industrial engineer who has had experience with operations research and computer work.

Questions. The problem involved in the Lindstrom Corporation case is not that production control is unable to do good scheduling and machine loading, but that the time available is too short to make a sufficiently reliable and costwise adequate schedule. Also, the time is inadequate to prepare all the necessary papers in time to inform every foreman about schedule changes affecting his department and new requirements and many other data needed to carry out production fast enough and in an efficient manner. The results expected from operations research and computer control are indicated in the case.

1. In your opinion how feasible is computer scheduling via operations research at the Lindstrom Corporation?

2. What basic difference is there between scheduling with the use of a Schedugraph and a computer in this specific case and what kind of difficulties do you foresee in the application of the latter?

3. Do you agree that scheduling at Lindstrom Corporation is really bad because of the unpredictability of the product mix, or are there other underlying causes? If you think the latter, indicate whether there is really a need for computer control in the production scheduling work in the first place.

4. Could these problems be remedied without recourse to computer work and operations research? If so, what would you suggest that management do?

5. What operations research technique (if any), would you say that Lindstrom Corporation should employ to transfer the production control function to a computer?

6. The case indicates what information management suspects that computer work will require and also that management is confident that all necessary information is available. What additional information do you think the programming in this case would require?

7. If you were the industrial engineer, how would you go about determining whether the company's production control problems are suitable for computer work, and whether production decisions can be made by operations research?

8. What limitations do you suspect that a computer-controlled decision-making process would present at the Lindstrom Corporation?

9. Do you think that both the savings and the advantages which the company expects from production control work as performed by computers are commensurate with the additional expenses which are involved in using a high-speed computer?

10. List specifically the results which in your estimation operations research—via the computer—could attain in the case of the Lindstrom Corporation.

chapter 16

Supervision–People, Problems, Action

THE SCOPE OF SUPERVISION

Although the discussion of preceding chapters centered around planning, it should be noted that activating the plan is at least of equal importance. Evidently, the purpose of the whole planning effort culminates in orderly and effective production. Neither planning nor activating has any meaning unless the two complement one another. Typically, the general thesis of this book is that of planning, but the aim has always been production; and the latter is nothing but a physical execution of manufacturing plans. Profitability is then largely a matter of enlisting human resources in the best possible manner, that is, in accordance with a carefully planned production program.

Although "supervision" implies management of personnel on the one hand and the activity of making things happen on the other hand, this discussion must be focused on results regardless of to what—managerial personality or supervisory skill—it can be attributed. Whether results depend on personal traits of supervisors or on the excellence of supervisory techniques per se is at this point not at debate. Good supervision must of necessity be defined in terms of results. If the departmental supervisor attains the financial goals the company expects of him, he is, ipso facto, a good supervisor—and he probably has good supervisory skills. Since plans will become reality (production) in the shop, the battle for production efficiency and the constant struggle for profitability will most likely be won or lost at this level of management.

Performance is the result of command. The one who commands the physical performance, which creates goods in industrial enterprises, is the supervisor. When the worker is being told what to do and how to do it, he is being supervised. Out of this personal contact between employees and supervisor results production.

The activating function is, of course, broader than supervision, but this discussion will be limited to that part of activating which involves this purposeful contact between men resulting in physical performance. Although it is undoubtedly true that the considerations in implementation of plans include many elements falling outside production proper, the fact remains that ultimately the supervisory group must overcome all obstacles and problems to make things happen in accordance with predetermined plans. Hence, the existence of the supervisory level makes it possible that goods come off the production line or that goods leave the loading docks.

The use of the word "supervision" in lieu of "management," should by no means imply that supervision is different than management. On the contrary, supervision refers to the same managerial activities as performed by any other (higher) member of the management team—that is, planning, organizing, directing, controlling, and coordinating—except that it is used in a somewhat narrower connotation. The surface difference lies in the fact that supervisors deal directly with the laboring group and direct the efforts of workers, dealing thus with a "physical" rather than mental performance; the main difference is that the jurisdiction within which supervision takes place is confined to rather narrow limits and the discretionary power accorded to supervisors tends to be curbed by rather explicit company policies. Nevertheless, the key to production success may well lie in the degree to which the supervisory group as a whole succeeds in taking authoritative action in dealing with the shop problems it confronts.

The fact that extensive help is given to the supervisory group—via the production, inventory, and quality control departments and through selection and screening of personnel—should not imply that the supervisory function is relegated to managment in name rather than management in fact. Production control and other supporting departments merely offer help because the vastness of modern production and the interrelatedness of many actions taking place in an industrial enterprise would, in larger companies, not permit unilateral action on the part of departmental foremen. The foreman of a given department seeing things from his perspective might have different ideas about keeping up his departmental efficiency than the collective interest of the company would conceivably demand.

It goes without saying that supervisory work is bound to differ from ordinary managerial work, because the former takes place in the noisy shop rather than in a quiet office. While the surroundings might differ, the activity of managing men is pretty much the same. Although it is true that some aspects of planning (particularly routing and scheduling), methods development, and recruitment and hiring of employees are often performed by staff experts, shop leadership has many other things to do. The crux of the matter is that these functions (nowadays performed by staff groups) can be accomplished by experts considerably better and faster than by supervisors. Considering the complexity and the large multitude of other functions a modern supervisor is committed to do in the shop, it would be next to impossible to assume capability on the part of foremen to handle all of them without some help. Therefore, it would be a mistake to believe that staff help relieves most of the headaches of supervision; on the contrary, staff aid might even make supervision considerably tougher, tougher in the sense that scientifically established plans to be carried out by supervisors are from now on (as a result of expert planning) so precise that even the best supervisors are bound to have difficulties in accomplishing them.

Where line supervisors themselves do all the work (that is, where no staff departments are attached to the line organization), they must make sure that machines are always ready for work, that the method the employee uses is indeed the one best way, that the materials are available when needed, that the forklift truck operator shows up in time to pick up the materials in the stockroom and take them to the respective machines, that the quality of work is under control, that employees are always occupied, and that employees work at normal work pace. Under such conditions, it is evident that something must give; either supervision will be mediocre or supervision will require the services of such extraordinary men that these men are just not available in adequate number. What is being considered an excellent result in light of do-it-yourself standards evidently becomes definitely mediocre performance under the line and staff arrangement.

Performance under the line and staff organization tends to be measured with different yardsticks. Since plans are precise as far as foremen are concerned, it is difficult to keep up with the tempo of work established by staff experts. In this kind of setup, foremen must concentrate on overseeing duties more than would otherwise be necessary, that is, under the easy-going pace they would set for themselves. In other words, the results which are expected are quite different under the line and staff organization than under the simpler line organization.

What has really happened is that supervisors have been forced to divest themselves of some of the requirements of managing, but, in turn, to specialize in handling men. This has been done by confining supervisory jurisdiction instead of spreading it too thin over the whole area of first-line supervision. Whereas the modern supervisor still performs most of the managerial work, he concentrates his efforts on those aspects of management which—by virtue of his personal contact with his men—nobody else could do. The favorable results in production efficiency clearly indicate that the division of labor between line and staff is fully warranted.

The upshot of this arrangement as far as departmental foremen are concerned is that output requirements have been raised. Furthermore, since a central Production Control department in a sense plans and directs the actions of all foremen, it has become of considerable importance that each foreman adhere to departmental work load assignments. Now, every foreman is a part of a big jigsaw puzzle and fits perfectly into the total picture. Therefore, every supervisor must put considerable amount of pressure on his subordinates to turn out goods in accordance with the requirements of the central office.

In addition to the above, changes in the economy and the society such as competition (profit squeeze), high taxation (that is, lower profit margins), labor union power, educational level of industrial workers, and the sociological importance of human relations made supervision considerably more difficult and demanding.

While early labor unions hardly hampered the actions of foremen, labor unions today tend to run the shop "along with the foremen." So far in this book the detrimental effects of labor union power on plant operations have been omitted. It probably should have already been mentioned that in face of labor opposition even the best supervisor is powerless; if the labor union disagrees with production schedules—however perfect they may be—the chances are that schedules will not be accomplished. If the standards upon which the schedule is based are attacked by the labor union, the very presence in the shop of a hostile labor union can virtually undermine supervisory authority. To get a good "mileage" out of men under such conditions is certainly a formidable task.

The rising level of schooling among workers is more a hindrance than a help to production foremen. In the technical sense, it is, of course, easier to explain the intricacies of a job to a better educated group, but in the humanistic sense, it makes the foreman's job more complex. Foremen nowadays must "butter up" their commands. Harsh words, effective as they might be, must be replaced by subtleties and diplomacy. In other words, the communication associated with order giving has been unduly complicated. Although frank and honest evaluation of the work records of a subordinate is the decent thing to do, the rule of the decade seems to be the "everything is made for love" approach. Because of this hypersensitivity due to changes in the composition of the work force (that is, in terms of better educated men) the supervisor's task is hampered rather than facilitated. While authority is still the key to effective supervision, foremen must learn to command performance through new methods. Sanctions under the constantly changing social system through which authority must be exercised have been very much reduced to subtleties with which foremen are not at home.

Structural changes in the society, such as labor mobility, greater job and income security (via labor union power), unemployment compensation legislation, relative abundance of jobs, and two wage earners in the family, certainly did not facilitate supervisory tasks. On the contrary, employees are often less willing to put their best efforts into their work, and it has become more difficult to handle men than ever before.

From the above it follows that in spite of the help furnished to foremen by staff groups, supervision over the years has become more demanding than ever before, even though labor relations and policy making were so far disregarded as fields in which supervisors might have to take an active part.

Theoretically, the "industrial relations" department should deal with problems arising from the administration of the labor contract. In practice, however, the supervisor is *the* industrial relations department in the shop. When problems arise, union stewards dicker not with the industrial relations people but with departmental foremen. While supervisors are theoretically not supposed to spend a great deal of time with "labor problems," the fact of the matter is that foremen cannot escape dealing with them. Among other things, supervisory effectiveness is measured by whether the supervisor can settle would-be grievances right in the shop rather than letting minor problems get inflated and end up at a conference table where embarrassed top executives must settle ridiculously bagatelle issues with union leaders. Barring harmonious labor relations, a large portion of supervisory time and effort is spent on straightening out potential or post facto labor problems.

To illustrate the extent of the burden still (that is, despite staff support) on the shoulders of supervisory personnel, a late president of the General Motors Corporation stated that GM foremen are not only managers of their departments, but[1]

> they participate in establishing *management policies* in both production and personnel matters. They have full authority to approve or disapprove the hiring, to supervise the work and to make work assignments of the employees under their supervision. They initiate wage increases, transfers and promotions. They are directly responsible for the efficiency and safety of their group. They have full authority when necessary to take immediate, appropriate disciplinary action for violation of shop rules, and other improper conduct of their employees. They are the first point of management contact and make the first management decision on all matters relating to the employees under their direction.

Now with the scope of supervision behind us, the question that becomes pertinent is how personnel capable of effective supervision can be found and how supervisory personnel must be trained to acquire all the necessary supervisory traits.

SUPERVISORY DEVELOPMENT

Foremen must possess basic human traits in order to qualify for supervisory positions. These human qualities can be classified into two basic groups: those which prospective supervisors must possess at the outset and those for which they must have at least the aptitude. Out of the following five supervisory characteristics, 1 and 4 must be present at the time of appointment; the others can be acquired shortly thereafter:

1. Personality and attitude

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[1] Quoted in *Foremanship Manual,* Foreman's Institute, 1960.

2. Knowledge of human relations
3. Ability to communicate with subordinates
4. Technical competence
5. Management skill

Of course, the more of these characteristics that are present even before the appointment was made, the easier and faster the transition from worker to supervisory status can be. Supervisory personnel can be recruited first of all from among the working group. Only after these internal sources are exhausted should other sources be considered. Every company should point out to the employee group as a whole that nobody is born to be a worker and must stay a worker, but that everybody who is *qualified* can become a manager.

Starting with the assumption that supervisory selection begins with a careful look at one's own shop employees, the personality and attitude of company employees must be scrutinized. A grouchy man, unpopular with and resented by his fellows, is evidently not a likely candidate for a supervisory position. To succeed, every man must be accepted as a leader among his fellow workers. He must be a man whose opinions, advice, and ideas are well regarded by the rest of the shop employees. Thus, these employees needed as supervisors are those who are already leaders, that is, who already have followers in the shop and who command respect among their fellow men.

In every shop and in every department, there are men who are more mature, more sensible, and more cooperative and who display more understanding of the problems of management than others. These are the men who should be approached with the proposition of a possible foremanship. It should be emphasized, however, that selection must, of necessity, be based on mutuality of interest rather than a unilateral interest. Qualified employees are not necessarily interested in switching from employee to management status. Some men just do not want to become managers and take home the headaches of a responsible job. Hence, before a man is approached, there must be a general idea whether he likes his present job and whether he is satisfied with being "one of the boys" or has higher aspirations.

On the assumption of the availability of a likely candidate, a careful inquiry into his attitude is necessary, because attitude is of vital importance to supervisory success. The man who considers profit as something which rightfully belongs to workers or who has the notion that management's aim is to exploit labor is not likely to succeed in a supervisory job. The men who must be sought are those who have proven ability to comprehend what goes on on the other side of the fence, who have the profound understanding that management also has a job to do, and who believe that in order to succeed we all must work together. These qualities are revealed over the years through willingness to work faster than necessary when the chips are down, through cheerful acceptance of overtime work even without advance notice, and through many similar traits. In other words, we need men who understand that management has problems and that industrial success depends on a sincere cooperation among men regardless of whether they are a part of management or labor.

It goes without saying that a supervisory candidate must have a good background in the various types of work which would fall under his jurisdiction. He must know the machines and their capabilities and, above all, how to operate them; he must be able to adjust the machines and to visualize the nature of products they can produce. Furthermore, effective supervisors must know or be familiar with all related operations and departments so that cooperation between various foremen is possible. Although blueprint reading might not be necessary, prospective supervisors should be able and willing to learn blueprint reading and any other technical skill which supervision requires.

It is not necessary, as mentioned earlier, that prospective supervisors possess all managerial characteristics at the outset—except that management must be reasonably sure that the candidates have the aptitude to acquire the basic supervisory skills. Whether someone has a rough background can readily be observed. Harsh- and rough-speaking individuals have an initial handicap in modern supervisory jobs. This is the opposite of what we would have said back in the 1920s. The same is true as far as the ability to communicate is concerned. Of course the assumption can be made that with "personality" goes the ability to "speak the language" of fellow employees.

Complete possession of managerial skill is not necessary, because thorough training—provided overall intelligence is adequate—can instill a great deal of supervisory skill. Particularly in line and staff organizations, it is easy to train supervisors in view of the fact that some of the more complex aspects of supervisory management are performed by staff men. Thus, the supervisor must learn to cooperate with various staff groups.

Provided that the desirable supervisory aptitude, personality, and attitude are available, supervisory skill should be developed through training as well as practical experience on the job. Nevertheless, training will not create supervisors overnight. Training merely gives the background to develop effective supervision. Generally speaking, actual supervision, coupled with appropriate training, makes the acquisition of supervisory skill possible.

SUPERVISING

Commands issued by a legitimate authority are usually followed by subordinates. Thus, the appointment of a supervisor to leadership duties nearly always implies compliance with the job assignments. To be continuously respected, authority must be exercised consistently from one occasion to another. For this reason, prior to commanding action, supervisors must consciously or unconsciously go through certain managerial mental processes such as planning and organizing. Although planning might be done by staff groups, the fact is that staff personnel can handle only the *impersonal* aspects of planning. Hence, regardless how we slice the cake, certain highly personalized elements of planning are bound to remain with supervisors.

Depending on the nature of scheduling, supervisors must, to a greater or lesser extent, appraise the work load assigned to their departments. If the work loads are assigned from a central office, they are very likely based on precise time study data. In other words, the work load *can* be accomplished. Yet, the supervisor might still have to figure out *how* the work assigned to him can be accomplished in the time allotted. The supervisor must see to it that everything within his department is well synchronized; not that some employees have a chance to loaf during the early part of the week and must be put on overtime work toward the end of the week. He has to anticipate possible machine breakdowns and work interruptions, and he must plan on working on those jobs first which can be shifted to an earlier period so that sufficient time remains toward the end of the week. Barring availability of time studies and schedules, the supervisor must be able to estimate the amount of time required to accomplish the overall work load assigned to his department.

Planning and organizing are somewhat related. When the work load is divided up among available workers, supervisory personnel must relate the type of work with employee talents. Assignment of the right man to the right job will always result in greater output than assignment of the wrong employee to the same job. Thus a careful contemplation of the nature of the job and the skill of employees is necessary. The supervisor must ask himself what personal characteristics the employee must have to successfully accomplish the job in question in terms of attentiveness, good nerves, and diligence; what skills are needed by the job in respect to strength, finger dexterity, ability to keep close tolerances, ability to operate given machines or tools; and what *degree of skill* is necessary in operating the machine tool. When an assignment requires no specific skills, the selection of the right man is evidently simple. When, however, special skills, along with personality factors, must be compared and a number of employees are equally well qualified, the supervisor must make a choice of men. In addition, factors such as likes and dislikes of employees must not be neglected. If, for instance, Tom, Dick, and Harry are available as well as qualified for a given job but neither Tom nor Harry likes to get greasy toward the end of the day, while Dick does not mind such inconvenience, the assignment should, of course, be given to Dick, even though Dick might be just a bit less qualified than the two others. It is an old truism that the one who likes his job does it well. It is, therefore, up to the foreman to match employee skills, likes, and other characteristics with the requirements of the job. Finding the right man for the right job is what is referred to, at the supervisory level, as organizing. And, as was pointed out, planning and organizing are closely interrelated managerial functions.

Although more will be said about effective methods to direct employees, at this point direction as a supervisory activity must be briefly explained. The everyday personal contact between supervisor and supervisee consists mostly of direction. The supervisor must plan the distribution of work assignments in such a manner as to get little resistance from workers, and the context of the explanation must also be planned, because the prerequisite of proper performance is still adequate direction. But what is adequate direction? Most teachers, for instance, feel that adequate instruction was given, yet during tests the fact becomes apparent that some of the less-talented students have still not grasped the concepts so carefully explained by the instructor. The same is true in job assignments. The supervisor must know his "birds" —whether to use a lengthy or brief explanation—and be reasonably sure that the employee precisely understands what he is supposed to do. Instructions may neither be ambiguous nor hard to understand. Prior to giving directives, relevant information must be thoughtfully sieved through the supervisor's mind to be sure that no misunderstanding is possible. The very tone of the instruction must be carefully planned. As parents learn to use harsh or soft voices to get the proper response from their children, so supervisors must employ different words and tones to get through to the worker. Some men react to strict orders; others must be asked politely. The end result is the same, of course, but if the supervisor had not used the right approach, the command would not have been as effective as originally intended. Common sense dictates that one not be diplomatic with a man who might misunderstand politeness. In other words, one must be versatile in the use of the language. Supervisors must learn to use language to drive the idea home to everyone. Because each individual is different, each must be commanded differently. Regardless of how instructions are given, it is essential that they explain 1) the nature of the job which the employee must perform, 2) when the job must be started and be finished, 3) the required quality of workmanship, 4) the output expected, and 5) the purpose of the job. It seems obvious that the employee who knows that the hole he drills in a piece of metal is for a piston going into a pump in a jet engine and that it must be a perfect fit to prevent leakage—and possibly an accident—will tend to pay more attention to the job than the one who has no idea what he is working on. An additional statement can readily place some responsibility for quality on a worker, whereas mere fear that the piece might be rejected and will reduce piece rate earnings might not always be as effective.

Command initiates production, but obedience is not only a matter of authority. Control must still exist to assure that commands are indeed followed. It might be faster for an employee, for instance, to use fingers than tweezers to take a workpiece out of a machine and thus attain greater piece rate bonuses. But the supervisor must enforce the rule that employees use tweezers rather than fingers for safety's sake. The same thing applies to output requirements. Unless the foreman sees to it—that is, does something about enforcing output quotas—a country-club atmosphere in the shop might easily develop. Lack of productivity might be the result of lack of discipline and control. The best control is little control, but, of course, not in the sense that the supervisor neglects enforcement of his demands, but rather that he uses subtle and unnoticeable means of control. Control over performance is the most important part of the supervisory job, because otherwise employees tend to produce less than their physical capabilities. Thus, the supervisor must exercise control over his subordinates in order to meet schedules and other obligations.

More will be said about the subtleties of control, but for the present purpose the nature of control must be emphasized. Thus, "remote control" techniques are far better than slave-driving techniques whereby supervisors breathe down the necks of employees. When output standards are established, control means that the foreman sees to it that employees accomplish work standards. In well-run departments, personalized control is the exception rather than the rule. If instructions make it clear to the employees what is expected of them, arguments can be kept at a minimum, yet control can be at the maximum. By checking constantly on output figures, indicated by employee time cards, supervisors can have a perfect picture of the performance of their subordinates. An appropriate scolding and an occasional disciplinary action might spread the word about the seriousness of control and will cause all employees to fall in line.

SUPERVISOR'S CONTRIBUTION TO EFFICIENCY

It has already been stated that supervisors can contribute to overall efficiency by performing their jobs as supervisors as well as possible. The general nature of supervisory activities was outlined in the preceding section. Here an attempt is made to indicate the how-to-do-it phase of supervisory work. At the risk of sounding redundant, let us illustrate the extent to which supervisory skill influences company profitability and productivity by having recourse to a further and deeper development of the previously explained ideas.

We have to assume that the supervisors in question have the personal qualifications and all other requirements listed previously. By doing so, we can make the further assumption that supervisors already know how to supervise and that they must merely learn how to improve their skills. Supervision is not something which one learns once and thereafter just knows how to do. A supervisor tends to grow; every new experience adds to his skill and enhances his ability to cut his department's costs of production. Since total profitability comes from the aggregate of all departmental efficiencies, as long as each supervisor does his best and runs his department at low cost, the total costs tend to be low. Obviously, some supervisors can run their departments better, and therefore at lower cost, than others. Thus, the statement can be made that good supervision can be appraised indirectly through the costs of production with which a supervisor operates his department. However, the underlying reasons for being good or bad supervisors are based largely on how well they can handle their subordinates as well as on their ability to use good psychology wherever human relations problems arise. Let us therefore see these two principal skills in more detail.

HUMAN RELATIONS

For sociological, economic, and other reasons, supervisors by no means have unlimited authority. On paper anyway, supervisors have all the authority needed to carry out supervisory duties. In reality, however, no supervisor can do what he would often like to do in order to discipline or otherwise bring into line his less cooperative subordinates. Although the right to fire as a disciplinary measure is available, the recourse to discharge might have serious consequences in view of labor union power. In other words, the foreman must think twice before threatening someone with discharge. Because firing does not guarantee that the next man will not turn out to be just as bad as the one just fired, supervisors are often hesitant to act. In other words, an exchange of employees does not necessarily solve a problem. A bad employee, with all the training he has received, might be better to have than a new employee with little or no specific experience. Therefore, it might be imperative to put up with even an undesirable employee. Thus, supervision under a system of checks and balances is not as simple as supervision in the military sense; there the authority of the superior is uncontested and always 100%. In industry, the foreman must learn to use some sort of magic by which people voluntarily agree to subject themelves to discipline and to being shifted from job to job, and yet be content with the superior's decisions. This skill at the supervisory level could be referred to as human relations.

To accomplish smooth flow of production, in spite of the don't-care attitude of workers, is indeed a formidable task. To maintain authority and yet adhere to accepted values and beliefs of the working group as a whole is as difficult as the navigation of rough seas. It requires a profound understanding of how and why people behave as they do. On the basis of such knowledge, supervisors must gage their actions.

Workers are often suspicious and mostly, of course, without cause. But no foreman is in a position to clear up employee misgivings on a large-scale basis. Supervisors must live with some degree of employee ignorance and overcome the difficulties which originate from lack of adequate understanding on the part of workers. It is difficult, for instance, to convince employees that they will not work themselves out of a job, because their experience attests to the contrary. Thus, to attain a high rate of production, even though employees feel as they do, is the task of human relations. The barriers to understanding and the traditional hostility which beset our industrial settings must be dissolved by the supervisor, at least as far as his own limited environment is concerned. Even though the worker who drills a hole in a lid which he then passes on to the next worker cannot feel proud of accomplishment, it is up to the foreman to give an employee some sort of pride in his work. The foreman must make every individual "important," and he must convince employees that their contribution is significant. The practical obstacle to creating such attitudes is, of course, that the drill press operator's *real* contribution is indeed not *that* important! Anybody can take his place! Yet, in modern foremanship, the foreman must at least aim at making everybody happy. At the same time, the foreman cannot fraternize too much with the worker, because he is a part not of the working but of the management group. To practice in this mixed environment—being *management* among workers—human relations is indeed an important skill which foremen must learn.

Handling Employees

It was stated in the preceding section that human relations at the supervisory level refers to managerial performance in an environment of checks and balances (that is, authority to command is mitigated by labor contract provisions) in which, despite inherent difficulties, production must be carried out to the satisfaction of both management and labor. This is a big order!

In seeking an understanding of how and why people behave as they do, the supervisor must learn as much about his subordinates as he can. Admittedly, it is difficult to get to know people intimately when the daily association consists exclusively of order giving and taking. Yet in the interest of efficiency, it becomes important to learn more about individuals. We are not only interested in manual skills they possess and whatever other skills go with them (reliability, safety, cooperativeness, etc.) but also in psychological make-up of subordinate workers. This should include emotional stability, interest, motivation, and maturity. The possession of this kind of knowledge will enable supervisors to place people into jobs for which they qualify as well as those which they like most—or to which they object the least.

Coping with Individual Differences. The handling of people is difficult, yet "management" means accomplishment through people. This is particularly apparent in production. While management merely plans production, physical performance is by people aided by tools and capital equipment in general. In the interest of efficiency it is essential that work assignments are so made that each worker will indeed perform in a specified manner. This requires a careful attempt on the part of supervisory personnel to cope with individual differences.

Whereas some employees are diligent, some others are not necessarily so. Obviously, reliable employees can be assigned jobs where a careful surveillance would be impossible anyway. Less ambitious workers must first be assigned only incentive or piece-rate jobs; eventually they can be assigned jobs in which the employee becomes a part of a diligent work crew. Here, through group pressures, even this man can be forced to exert himself a bit, even though it is not his nature to work hard. A further solution is, of course, to assign the man to an easily controllable job.

Short-run jobs need men with relatively high intelligence. Thus instruction and training time must be kept at a minimum, and the foreman must be reasonably sure that the employee can work independently. The assignment of simple, but long-run jobs, in turn, presupposes the selection of a different employee, who presumably will need lengthy and detailed instruction in addition to a short training period, yet who can perform satisfactorily after overcoming the initial difficulties. Thus, aptitude and intelligence might be used as the criteria of selection. Some men like to work on details; others do not. The former type might be assigned to set up jobs or to jobs where attention is needed; the latter type, to long-run but simple jobs.

Some employees are extroverts; others are introverts. This kind of stereotyping of peoples can possibly indicate suitability to group or individualized duties (for example, a job hidden in a corner of the shop). An assembly line, along a long bench, is an ideal spot for a female employee who likes to gossip and be with people. (As a rule, conversation is permitted on some jobs as long as it does not interfere with production.)

Liking or disliking a job might be associated with personal comfort. Some employees like jobs in which they can sit during working hours, whereas others prefer to stand and move around. If the foreman knows these personal preferences, he should, of course, accommodate his subordinates as much as he can. The satisfied employee can be handled much easier, since a mere threat of taking away the well-liked job will act as an instrument of control.

Educational backgrounds and intellectual differences between people particularly deserve a great deal of attention. Better educated employees must be treated according to their background. Obviously, instruction and explanation must be commensurate with their mental skills. A man with grade school education must be given an explanation entirely different from that given to someone who has finished high school or who has even had some correspondence courses in college subjects. Particularly when it comes to grievances, the intellectual level of the employee in question becomes of paramount importance.

Certain prejudices of employees must be accepted rather than objected to. If an employee is prejudiced against a given nationality, race, religion, or political party, it is not the function of the foreman to reform him; he must overlook the prejudices and assign the individual to a group where his prejudices can do no harm.

The question of status is of great importance to employees in the production environment. Employees tend to gain a certain shop status as time goes on and tend to expect job assignments in accordance with the status they believe they have attained. It is, of course, immaterial how justified these feelings are, the fact is that they are present and employees consider shop status an important concomitant of a job. Therefore, the foreman should endeavor to make job assignments as nearly in accord with employee expectations as possible.

Some workers are accident-prone or sometimes outright clumsy in certain work situations. It is essential, therefore, that foremen watch out for these human shortcomings and not assign a man to a job where his personal handicap would interfere with his performance.

Human characteristics dealing with mechanical skills may not be neglected either. Through observation, foremen will notice over a period of time that some men can, for instance, work at closer tolerances than others. Therefore, these men should be assigned the kind of jobs where accuracy is important. Thus, over a period of time employees tend to gravitate toward jobs they like, in other words, which they can do really well. Finger dexterity, special aptitudes, job desires, and special skills become known to the foreman as a result of being in the shop with his men. When it comes to selecting a worker suitable to a job, he tends to look for the relevant personal skills.

Absenteeism and Tardiness. The handling of people who tend to be late or absent requires special attention. In a production setup where foremen have to meet predetermined production deadlines, lest another department and possibly the whole plant be held up, it is necessary to make sure that everybody is present when needed. Unless people show up for work on time and with a reasonable degree of regularity, foremen are unable to plan the accomplishment of production schedules and are forced to make too many improvisations that result in costly delays. Obviously, a department that is always behind schedule can disrupt the general flow of production between departments and constitute a sore spot in the whole production system. Employee tardiness can be particularly serious in continuous production where, because of one worker, the movement of the whole production line might be held up. In multiple-shift operations, it would be necessary, for instance, to hold over an employee from the preceding shift until the tardy man arrived, causing overtime costs, inconvenience, and, of course, a steady headache for the respective foreman.

The question, of course, is what can be done by the supervisor about absenteeism and tardiness. All we know is that absenteeism and tardiness are costly to the company, because they reduce the effectiveness of the foreman's department and because they have a bad effect on employee morale as a whole. A possible remedy is a frank conversation with the employee during which it must be pointed out that the frequent absenteeism or tardiness places a burden on fellow workers. Little emphasis should be placed, however, on the fact that it creates tremendous problems as far as management is concerned. The employee can be better motivated by his solidarity with his own class. But even more effective can be the systematic assignment of the notoriously tardy or absent worker to group-incentive jobs where the group pressure can do more good in a shorter period of time than an hour of preaching by the foreman. This method also has other advantages! If it appears desirable to discharge the employee in question, the objection of the labor union can be mitigated simply by lining up coworkers against the continuation of this worker's employment. Thus, the union steward becomes more sympathetic to the problem of management as a result of employee support of management's decision. A disciplinary measure with doubtful effectiveness is the deduction of pay, say, of 15 minutes pay for every 2 minutes of delayed arrival. Whether this is effective at all depends largely on the provisions of the labor contract relative to pay deduction.

Of course, if absenteeism or tardiness results from the job itself—for example, if the employees must work too many hours overtime and are consequently sleepy the following morning—the foreman should simply eliminate the cause in order to solve the problem.

The supervisor can cope with curable causes for tardiness or absenteeism, but if employees have no legitimate excuse and none of the above suggestions seem applicable, a transfer or even a more drastic step might become necessary. Disinterested employees are nothing but a burden on any department, and if the employment situation does not warrant keeping undesirable elements on the payroll, the discharge might be the best remedy. By not having tardy or absentee employees, arguments over penalties and the causes for delays can be eliminated.

SUPERVISION AND LABOR UNIONS

The primary function of the foreman is to make things happen, but his ability to produce results depends largely on the labor union. Without misleading the student, it can be said that the net effect of unionism is that employees tend to go to the union steward rather than to their foremen. Thus, authority of the foreman seems to be counterbalanced by an undefined authority of the union representative, who, incidentally, is merely another worker. This often forces foremen to deal with their subordinates with kid gloves. Someone has said that the net effect of unions in today's industrial enterprises resembles intimidation capable of preventing foremen from running their departments as they consider necessary. Many decisions which would ordinarily be made on the spur of the moment must be delayed in order to give sufficient thought to their possible consequences. By the time the decision is made, it has already lost its effectiveness. The fact that a supervisory decision must be "air-tight" in the sense that the union cannot get hold of it and carry it up to higher levels—via the grievance procedure—for reappraisal makes supervisors hesitant. In this kind of environment, workers are apt to be more confident in their own "strength" relative to their bosses and tend to become more difficult to handle than in a nonunion plant.

In the final analysis, the problem resulting from the labor union's presence in the shop is largely one which concerns the foreman. Whereas both labor policy and labor contract are negotiated at top levels, it is always the foreman who must live with the decisions, whether good or bad, which were made at policy levels. As a matter of fact, the administration of the labor contract is in effect more in the hands of the foremen than in the hands of the industrial relations department. Because of his everyday contact with employees, it is the foreman who is the mainstay of the company's labor relations program. This problem is so important that we devote the following section to it.

THE SUPERVISOR AS THE KEY TO LABOR RELATIONS

Despite existence of an industrial relations department, management looks to the foreman to carry out its labor policies as laid down by the labor contract. Through personal leadership, foremen often compensate for the shortcomings of the labor contract. By dealing skillfully with employees, union stewards, and other union representatives, it is possible to get agreement even on issues which otherwise would be in violation of the labor contract. (Of course, permission must always be received in written form.) Although there is some sort of animosity between labor and management, no one should assume that the labor union is a villain, because it is not. A good foreman can deal with and settle things with the labor union in a straightforward manner. The union has a job to do in protecting the interest of labor, and a foreman willing to recognize this prerogative can always get further than the one taking a stand against the union. A good foreman can, even against the conviction of the union steward, convince the labor union that there are and must be exceptions to every rule; when such exception is needed, he gets it.

Since the foreman is in a strategic position, he must also answer questions that employees pose relative to contract interpretation. For this reason, foremen must be familiar with contract provisions. The printed words alone do not always satisfy the inquiry. Well-spoken words, particularly when properly interpreted in the worker's language, can eliminate possible arguments. In case of alleged violation of the labor contract, the foreman should be prepared to defend his, and management's, position with a plausible answer. To make employees understand the situation, the educational background and intellectual powers, interests, and social status of the employees involved must be known. If done in legal language, even the best educated worker might walk away dissatisfied.

At times it might be necessary to acquaint workers with some of the economic facts of life. Of course, to do so, foremen must have a working knowledge of some of the elementary concepts in economics such as wages, costs of production, prices, profits, productivity, and competition.

Queries poorly handled by foremen can turn into grievances; and grievances, even if amicably settled, might leave scars that are manifest in willful sickness, soldiering on the job, and tool breakage. Thus, the first and foremost task of production foremen is to settle issues and, whenever possible, prevent problems from developing into full-fledged grievances. The second task is to prevent a grievance, if already formally submitted, from being kicked up to higher managerial levels for settlement.

SETTLING GRIEVANCES

Certain dissatisfactions can be resolved in the shop. But to resolve them, foremen must be fully acquainted with provisions of the labor contract in all its ramifications. Herein lies a very important problem foremen must learn to cope with, namely, the show-down situation. Labor unions occasionally test given sections of the contract and may submit grievances by using the naivité of a given supervisor as the "disguise." Foremen must be careful and watch out for possible traps. Particularly in such situations must supervisors be on their toes and use good judgment. Ordinarily, however, most employees turn to their union stewards with legitimate "gripes," which—when taken up with the foreman—can be settled right then and there.

In settling grievances, the issues must, of course, be settled on the basis of "principles." Although foremen would often like to settle things on the "merit" of the issue, the labor contract sets the procedure and problems must be settled in accordance with the appropriate paragraph of the labor contract. For this reason, an intimate acquaintance with the labor contract is a must in most supervisory positions. The fact that an industrial relations department might aid in the settlement does not relieve a foreman of his immediate responsibility.

When dealing with problems, foremen must look out, of course, for the human element which tends to be inextricably interlaced with arguments regardless of whether wage rates, promotions, demotions, or disciplinary problems are involved. Although the company might be perfectly in the right, meaning that the employee initiating the grievance is in the wrong, the victory on the part of the foreman should never be a well-publicized one. Any result must be soft-pedaled in order to let employees save face with their fellow workers. While winning an argument might be important, as far as the supervisor is concerned, he should never claim victory. He should merely retain his authority in the eyes of his subordinates. Yet, a foreman should never, no matter how serious the argument, show a superior attitude. Employees seem to have the tendency to gang up on the supervisor with corresponding loss in his authority and deterioration of group morale. The latter in turn affects group efficiency.

It is not the purpose of this section to rehash the grievance procedure, but merely to point up the foreman's role in settling common arguments in the shop. The fewer these arguments and the better they are handled, the better mileage foremen will get out of their subordinate employees. A grievance takes not only the foreman's time but also that of several employees—who, incidentally, are supposed to work—and, of course, that of the union steward—who is also a worker and who is also supposed to work—and possibly that of the superintendent. Thus, several people are involved. In addition, dissatisfaction can spread and the efficiency of the whole department as well as other departments might be adversely affected. It is, therefore, of utmost importance to prevent grievances if at all possible or to settle them at their source. This does not mean that the foreman should settle all grievances, but he should straighten out all those which can be resolved at the supervisory level.

Wage Rate Arguments. The most frequent arguments center around wages. Although wage rate problems are the easiest arguments to settle, they are annoying because they often involve arguments about pennies and about misinterpretation of holidays, the starting date of wage boosts, deductions, and piece rates. The ease as far as settlement is concerned results from the fact that records will prove that the company did not "gyp" the employee. Nevertheless, it takes time to convince employees. Of course, once the records are checked, the argument can usually be settled amicably. One basic rule about handling this kind of argument is that the foreman should never be engaged in arguments in front of other employees or where workers can gang up on him. Arguments should be handled in private between the foreman, the union steward, and the worker. The three parties involved should not disappear from the shop floor, however, and spend a considerable amount of time in the office. Rather, the foreman should ask the personnel or labor relations office to prepare all the records. When the records are gathered, the steward should have a chance to study them. When a tentative agreement between steward and foreman has been reached, the employee should be contacted. This should happen, however, right after the shift is over rather than during the workday.

Serious wage arguments might result from the wage incentive system. Actually, the argument might center around the output quota rather than the wage rate per se. (Wage rate problems are usually settled in the contract resulting from collective bargaining.) Thus, output requirements versus incentive pay must be resolved.

Obviously, employees are adamant about their right as to incentive bonus. If the amount received is smaller than expected, employees can get easily excited. As a rule workers ask the foreman how come the bonus is less than they expected. Employees often count the rejects into their output; often employees might not understand the borderline where incentive earnings begin; or employees might not have punched in on the job correctly. Whatever the problem, the foreman must be able to settle it. If the payroll department made an error, the foreman should not hesitate to make the apology. Occasionally, it is worthwhile to accord a few cents to the employee even though the foreman is certain that no error was made. Care must, however, be exercised in the latter case in order to prevent employees from getting accustomed to "gypping management." In many companies, the foreman is instructed to follow the rules no matter what.

Of course, if the standard (the basis for the wage payment) is severely attacked, it is no longer up to the foreman to settle the issue, because the core of the whole wage payment system might be at stake. In such cases the foreman should hold off the union steward until the industrial relations and the industrial engineering departments are contacted, superior officers have been informed, and formal judgment on the part of management has been reached. If the information thus gathered does not permit settlement, recourse to the grievance procedure is almost inevitable.

Seniority Arguments. Even though seniority rights are vital to workers, seniority arguments are relatively simple to settle. Yet possibilities for error on the part of foremen are plentiful and must be avoided if possible.

When job security is at stake, employees are very unyielding about imagined or real infringements on their seniority rights. Recourse to records usually indicates the date of employment and current seniority status. Hence, the records would usually help in the settlement of most cases in which the issue of seniority arises. But, in the turbulence of a busy day, the foreman might forget about seniority and assign jobs to men who, according to the seniority regulations, are not entitled to them. It might be an unintentional oversight, but the foreman is in trouble.

Occasionally, an employee who returns from a legitimate leave works a couple of months prior to a general layoff. When this employee is not laid off first, an uninformed plaintiff might turn immediately to his union, stating that he has more seniority than the next fellow who has not been laid off. It is apparent that an employee thought that he was in the right, but, of course, an explanation might clear up the issue. If the foreman contemplates a layoff and two people who possibly could argue about the layoff might be involved, it often seems wiser to hold both and lay them off simultaneously. Thus, senseless arguments might be avoided.

The seniority status is, from the point of view of efficiency, a real hindrance to first-line supervision. The difficulty arises from the fact that the supervisor must, according to most labor contracts, give the first chance to those who have seniority rights. A new job which might pay better and which might be suitable to a younger employee should, when using common sense, go to a young man; but according to the rule, the foreman is often forced to pick an unsuitable old-timer. When the supervisor is busy and needs a fast and skillful man, he would most likely pick a young employee. But he must give a chance to the older men who probably have accumulated more seniority rights. Something is evidently wrong with the seniority system, because a mere accumulation of years of service does not necessarily mean better qualification for a job. A younger and less experienced man might conceivably perform better than an older man. The same thing is true in cases of overtime work distribution and layoff. But in order to avoid trouble, it often does not pay to take the best road, because, in the long run, it might lead to more harm than good as far as the respective supervisor is concerned.

Incentives and Standards. In a preceding section mention was made of wage incentives. Obviously, employees tend to argue about these issues because their paychecks might be involved. Customarily, however, the output standard is attacked first. This kind of argument can be extremely touchy, and most foremen try to avoid it. Yet the argument must be settled in the shop.

The problem of incentive development was explained in Chapter 6 in connection with job shop operations. If we recall, the main function of the incentive system is to stabilize production at a desirable level. Thus, a standard is established on the basis of careful time study and an output quota is finally set. What kinds of argument might arise with the output quota? Well, the standard is valid as long as the method of performance remains the same. However, the methods undergo constant improvements leading to a constant amelioration of operation time. At the beginning the change is so small that it can barely be noticed, but after a series of little changes, the operation time might be cut in half. As a result, the incentive increment becomes greater and greater and employees start making unusually high bonuses. When management, through the payroll department, learns about this, it is not unusual that the standard or the incentive pay is adjusted. This, of course, causes a serious problem to the foreman under whose jurisdiction the job is being run.

The reverse might also happen. In many instances, the quality attainable with a standard is so bad that the company decides on closer tolerances. But the output standard is not adjusted. Employees might file a grievance because of an "unattainable" standard. Although the foreman cannot handle the problem, for standards are set by the industrial engineering department, his main contribution might be to take the matter up with union representatives and suspend arguments until appropriate study is made.

Some of the arguments center around the "loose" standard rather than the "tight" one. When a method change was made, it is conceivable that the job was closed out. Although the labor union probably was notified and the labor union actually agreed to the change, the job might not be run for another year or so. When a year later the job is assigned to a worker (who probably remembers the rate he had on the job a year ago), he might file a grievance in the sincere belief that the standard was changed because management "wants to kill all the good jobs." Employees tend to rebel against speed-up and quickly run to the union steward with complaints of this kind. Of course, the foreman must explain and submit evidence until the issue is finally settled. For this reason, it might be better if the foreman anticipates possible problems and, when he turns over the job to the employee, mentions the changes and the union-management agreement on the changes. He might well inform the union steward also. In this way, it is possible to prevent a complaint from becoming a grievance.

The labor contract usually defines the conditions under which standards can be changed and what management must do to institute a change. Thus, the foreman must be careful to follow the rules to the letter to prevent serious arguments. In many instances foremen are at fault when arguments develop. The fact may be that the foreman changes a method but fails to notify the industrial engineering department about the change. Over a period of time, the various changes become so significant that a study should be made, but because the changes were not officially registered, management loses its right to adjust the pay. Thus, it is important that foremen report every change which might be remotely connected with wage incentives and output standards. This precautionary measure might be well worthwhile. Of course, it is another burden on the first-line supervisor. On the other hand, if a supervisor wants to function properly, he must do whatever in the long run facilitates his job.

The main trouble, of course, is that many foremen do not keep records and often forget the changes which were made. Despite the legitimacy of the change, employees will argue unless the foreman was the first to mention something about a possible change. When employees suspect foul play, it is difficult to appease them without considerable loss of time. In other words, the foreman should anticipate such problems and be prepared to meet employee or labor union objection.

Of course, employees are often justified in being suspicious about speed-up. In the not so distant past, managements did not make careful enough time studies. When a standard was set, employees might have discovered that it was wrong, but, of course, nobody notified management about the loose standard. When management finally discovered the error, it was usually too late to change it. Nevertheless, management deliberately changed the standard, and this practice became known as speed-up. In light of these past happenings, the employee group as a whole suspects foul play every time something seems out of the ordinary with a job. The foreman must therefore make certain that employees always know what is expected of them in terms of output, what the incentive pay is, and at what output level the incentive increment begins. The foreman must be extremely careful with this kind of thing because the paycheck is the most sacred thing to most employees.

Not only are arguments of this kind annoying and apt to create problems way out of proportion to their importance, but foremen face these problems day in and day out. One of the problems, of course, results from the lack of adequate cooperation between the time study people and the production foremen. Because the standard is used to set production schedules, foremen often close one eye when errors in the time study are made. They are former workers themselves and know that the standard is loose, but they tend to protect themselves against stiff production schedules. In the long run, however, they do a great deal of harm to themselves as well as to their company.

Job Assignment. Some of the many grievances arise from arguments over job assignments. In many cases, employees are merely insubordinate; in other cases, however, the workers refuse to do something as commanded in the sincere belief that a contract provision is being violated by the foreman. As a rule, the contract clearly states what an employee must or must not do. Recently, for instance, an argument became a grievance and finally a wildcat strike because the labor union protested "over management's [a foreman's] requirement that a forklift operator unload pallets . . . stacked seven high and that operators should get off their machines to help truck drivers."[2] Underlying the argument over loading procedures was, of course, the fear of unemployment as a result of destroying a job via mechanization. This kind of argument is prevalent nowadays, because mechanical handling devices, automatic switching devices, and many other mechanical improvements tend to eliminate jobs and employment. Hence, the labor union is very eager to protect jobs wherever loss of a job appears imminent.

Under union-management agreements, job assignment is evidently not always as simple as in the absence of a labor contract. It was mentioned earlier in a different connection that a foreman cannot indiscriminately pick the best man for the job, but must select one from among those with seniority. Here the seniority gave the men the first crack at a job; if there is a job assignment paragraph in the contract, special mention is made about the manner in which jobs must be distributed among the different job grades and employees.

Problems resulting from the workers' job classification can also cause a great deal of headache for the foreman. A case in point is a job which has been classified to require the service of a first-class machinist. While under certain circumstances the foreman could assign a second-class mechanic to do the job without loss of efficiency, before making such an assignment, he had better think twice.

Disciplinary Actions. The saying that "good supervisors have no disciplinary problems" is true to some extent. Whereas every supervisor has some difficulty with a few employees, the good supervisor is able to handle the situation so skillfully that it appears that there are no problems in his department. When we have such a variety of human interests as in factories, it is apparent that some people work only to earn their living and others like to work. Either group can be further divided into responsible and irresponsible, diligent and lazy, and young and old workers. Occasionally, workers must be disciplined for something they should not have done.

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[2] *Business Week,* April 16, 1960, p. 142.

Some men like to work as long as they get all the "nice" jobs. When a "bad" job is assigned to them, they refuse and the supervisor is forced to take some sort of disciplinary action. Some workers like to visit in various departments and, of course, they visit each other on company time and expense. These men must be occasionally disciplined. People work slowly—soldier on the job—occasionally and must be brought to their senses. The supervisor, since all these happen on the job, is the disciplinarian.

Because one of the main rules of proper disciplinary action is uniformity, it is essential that foremen use the same disciplinary measure for each offense of the same kind. One of the main difficulties with the penal system, for instance, is that men will have to serve different time for the same offenses depending on who was the judge. In industry, disciplinary measures must be uniform throughout the plant—the same offense, the same penalty.

Some labor unions participate in disciplinary action through the labor contract in which some of the common rules of such action are laid down. Thus, certain predetermined penalties are established for certain offenses. Although the union has nothing to do with disciplining per se, any action which appears to be contrary to the agreement laid down in the labor contract can be objected to through the grievance procedure. In other words, the foreman has serious limitations so far as disciplinary action is concerned.

In face of such impediments to successful supervision, that is, union interference with disciplinary action, one must indeed wonder how it is possible to carry out production when even the fundamental disciplinary instrument in the hands of the supervisors is regulated by the labor union through the labor contract.

Transfer, Promotion, Discharge. Authority is an essential element in managerial positions. It is a power by which commands can be exercised and response can be expected. When some elements which make up this "power" are lacking, authority is incomplete, discipline becomes lax, and the enforcement of commands depends largely on the good nature of the employees. Therefore, in industry every possible element which could strengthen the authority of supervisory personnel must be accorded to the first-line supervisor. A supervisor who has all the outward signs of authority—the right to hire, fire, transfer, promote, and demote—does in fact have all the fundamental elements necessary to enforce his commands. By the same token, the one who cannot fire or for whom discharging an employee is made extremely difficult, and who has little or no say about who will be promoted, transferred, or discharged, also has very little authority in the eyes of subordinates. Thus, this particular supervisor has a considerable amount of difficulty in running his department effectively. It is not the authority that exists on paper that counts, but authority demonstrated through action.

The labor union might affect some of the above supervisory functions through the labor contract. As a result, there is a built-in handicap which hampers the supervisors in carrying out their duties. If employees must be promoted on the basis of seniority rights rather than on the basis of merit, there is absolutely nothing in the hands of the supervisors with which they can reward reliability, persistent good performance, and diligence. The same thing is true in regard to transfer. Where contract provisions regulate in definite terms how transfers can be made, the transfer as a disciplinary measure or transfer as a remedial measure loses its effectiveness.

Without further discussion on this subject, it is apparent that where the outward signs of authority are severely curtailed, supervisory authority is proportionately curtailed. Regardless of how excellently human relations are practiced, nothing can replace the force unlimited authority can render to supervisory personnel.

SUMMARY

The Supervisor's Contribution to Efficiency

Production efficiency, the goal of every enterprise, is a composite of departmental efficiencies. For this reason, in the overall picture, each foreman's effectiveness is of utmost importance. Despite the excellence of planning, if supervisory personnel are unable to make people act in accordance with predetermined plans, planning loses its extraordinary importance. Accordingly, the supervisor is by any measure equally important as the planner. Either poor planning or mediocre execution can lead to inefficiency, and therefore either one is undesirable.

Because of the importance of supervision, top management attempted to enhance supervisory effectiveness by clarifying supervisory duties on the one hand and by simplifying supervisory responsibilities on the other. This was done through the functional separation of supervisory duties into line and staff groupings. Activities considered delegable to staff departments were taken away from the foreman. Thus, the latter remained with a certain limited number of tasks, primarily those which necessitated his personal presence in the production shop. The conclusion is that the only thing foreman should do relates to production itself: get the job out and effect the changes needed as time goes on.

In the absence of supporting departments, *planning* is done by the foreman. This involves accurate scheduling of production, meeting delivery promises without overtime work, and meeting them with the most economical utilization of productive resources. *Organizing*, as it applies to the supervisor, means the assignment of the different jobs to the men who are assumed to be the most capable of doing that particular kind of work. This necessitates intimate knowledge of skills and personal characteristics of subordinate personnel. *Directing*, always a part of supervisory work, requires the ability to explain the how-to phase of the job assignment to the workers. Here a great deal of common sense and know-how of human relations is necessary. *Controlling* and *coordinating* are related functions. The foreman must exercise control over achievement of predetermined production standards. This requires a steady control and personal presence of the supervisors. The coordinating phase of foremanship in turn requires that the foreman synchronize material delivery, setup, and tool and die making with production so that all elements of production are available when needed. To look for a materials handler at the last minute would result in idle time for men and machines.

To enhance production efficiency, the impersonal aspects of supervision were allocated to staff departments who, through specialized skills, can do better work than busy supervisors could do. Planning, not being directly related to turning out products, can be delegated to the production control department; by the same token, to say that time study is essential to planning and control is not to say that the foreman himself must take the time study. Thus, time study men are assigned to aid supervisors. Coordinating the stockroom activity with materials handling is also essential to production, but it is certainly not inherent in foremanship to chase the fork-lift operator to bring raw materials to the machines so that production can start. Therefore, management of modern industrial enterprises established staff departments with the duty of strengthening foremanship. The latter is narrowed down to picking the right man, assigning him to a job, and finally to instructing him and controlling his performance. Otherwise, supervisors must merely follow as best they can the overall plans as worked out by staff people.

Even though modern production systems seem to reduce supervisory duties to mere activation of predetermined plans, supervision has not been facilitated to the extent commonly believed. The fact is that experts now do the complicated planning work for which line foremen seemed to lack both time and technical knowledge. But this also means that the plans thus established are now so precise that it is difficult to accomplish them when labor unions challenge management prerogatives or when the unemployment compensation system and job opportunities force foremen to deal with his subordinates with kid gloves. Thus, it is estimated that, as a result of centralized production control, from 100% to 200% more work can be scheduled than used to be possible when it was done by the foreman. Thus, it is up to the foreman to get this double or triple production load out of employees at a time when it is no longer as easy to deal with the force as it was before World War II. The added departmental work loads and the difficulty with the "new labor force" makes the modern foreman busier than ever before. While it is true that staff departments relieve the foreman of some of his duties, it is equally true that foreman have to turn out considerably more work than ever before.

THE SUPERVISOR'S ROLE IN LABOR RELATIONS

The overall quest for efficiency tends to endanger the job security of those workers who are inefficient. To protect jobs and incomes, the labor unions put all sorts of roadblocks in the way of supervision. Job security, output restriction, and performance control are factors strictly related to efficiency, and since the labor union is also vitally interested in these factors, it is the supervisor who must cope with the problem despite the availability of an industrial relations department.

The labor union tends to challenge the foreman's authority through the contract, to which management is usually forced to agree. Management, through collective bargaining, tries to agree to a contract which hampers it as little as possible. Nevertheless, the labor contract tends to curb supervisory authority. Thus, the supervisor is not perfectly free to discipline, transfer, or discharge his subordinates. He must accept the employee with the greatest seniority rather than the one who is the most capable; he must often assign to jobs men who are not necessarily qualified for them. In a production system foremen must not only meet tough standards of performance (as established by the production control department) but must handle workers as if they were "clients" rather than employees. In addition to supervisory duties, supervisory personnel must settle the issues arising from alleged violation of contract and prevent grievances from becoming "big" issues, yet operate their departments efficiently at the same time. If a trouble develops, even though there is an industrial relations department, the shop steward goes to the supervisor and not to the industrial relations department; hence, the supervisor is both the executor and the mediator. Supervision requires modern foremen to be supervisors, good listeners, good leaders, good friends, and tough task-masters. Evidently, these are not necessarily compatible human qualities.

THE RESPONSIBILITY FOR ACTION

Action results in a finished product and permits billing the customer. Thus, profit is produced in the shop. The responsibility for making profit, the most important goal of modern industrial production, rests to a large extent on the shoulders of the first-line supervisor. As long as each supervisor accomplishes the work assigned to his department in the manner that efficiency requires, he has contributed his share to company profitability. But, considering the above handicaps and difficulties, it is apparent that foremanship became a formidable job—despite all sorts of supporting staff departments.

Recognizing the paramount responsibility involved in foremanship, progressive managements accorded appropriate authority to foremen so that they can assume their important role in the production process. Thus, General Motors Corporation considers the foreman one of the most important of management personnel and accords him all the rights and privileges accorded to higher ranking members of management. The assumption is that if the foreman is responsible for results, he must also have the right to make decisions which might otherwise handicap his freedom of action and tend to undermine his authority.

QUESTIONS

16-1. Define the supervisory function. State specifically those managerial functions which do not fall under the jurisdiction of the modern supervisor.

16-2. What advantages are derived from supervisory specialization?

16-3. How time consuming is supervision where the supervisor himself is responsible for planning as well as executing his own departmental work?

16-4. In a society where the labor union has a foothold in nearly every industrial enterprise, how much added burden is placed on the shoulders of the supervisor as a result of the presence of the labor union?

16-5. Would you say that the labor union is a roadblock to supervisory efficiency? Why?

16-6. To what extent is supervisory authority affected by the presence of the labor union in the production shop?

16-7. How much easier is supervision when the production control department performs some of the supervisory functions?

16-8. How much help is rendered to the supervisor by industrial engineering, production control, and other staff departments and to what extent is this help appreciated by most supervisors?

16-9. Did supervisory effectiveness increase or decrease as a result of functional separation of supervisory duties?

16-10. Do you agree with the statement that "no matter how excellent the production plan, unless supervision is also excellent, production will fall short of expectations?"

16-11. What is the role of supervisors in industrial relations?

16-12. Does human relations have a place in modern production shops? Why?

16-13. Specifically, what does human relations mean in a shop environment?

16-14. Would you say that a supervisor who has little knowledge about the jobs under his jurisdiction but tremendous ability to get along with people could attain good results?

16-15. To what extent is success related to technical knowledge of the jobs under the supervisor's jurisdiction?

16-16. How, if at all, is good supervision related to good human relations?

16-17. To what extent are supervisors found to tolerate insubordination where provisions of the labor contract tend to regulate many things ordinarily falling under "managerial prerogatives?"

16-18. Assuming that the supervisor is responsible for results, in terms of output volume, quality, and costs of production, how much authority must be accorded to him and how much say-so should the personnel, the production control, and the quality control departments have?

16-19. What must a supervisor know about the employee whom he picks for a given job?

16-20. What role does the supervisor play in the grievance procedure?

16-21. To what extent can supervisors contribute to company profitability?

16-22. What is the role of the shop foreman in budgetary and cost control?

16-23. What attributes, personal and professional, must a good supervisor have in order to succeed?

16-24. In some industrial enterprises, management gives preference to foremen with college education. Do you agree with this policy?

16-25. How can foremen exercise control over lazy employees in a production environment where labor unions openly advocate restriction of output as a desirable union objective?

16-26. What can supervisors do about tardiness and absenteeism?

16-27. How can foremen settle most wage rate and piece rate arguments?

16-28. Would you say that "seniority" is a roadblock to supervisory freedom?

PROJECTS

16-1. Write up the "ten commandments" of good supervision.

16-2. Develop a number of criteria whereby one can appraise supervisory competence. Indicate precisely the technique of measurement and the grading scale to given factors.

16-3. Select three industrial enterprises in your home town; possibly one engaged in continuous production, another in repetitive production, and a third in intermittent production. Through personal interviews with company officials, including foremen, find out a) the extent to which authority is given to the foremen in matters of hiring, firing, promoting, and transferring, b) how many staff departments aid plant foremen, c) the relationship between the various line and staff members of the production organization.

16-4. Assume that you were appointed to head a supervisory training department with the task of conducting a 6-weeks training session. The participants consist of *new* as well as old supervisors. Outline the subject matter which you intend to present in each 3-hour session.

16-5. Differentiate between the five managerial functions of planning, organizing, directing, controlling, and coordinating as they apply a) to the executive group and b) to the supervisory group. Specifically, list one by one the kind of things a top executive would plan and the proper subject matter of planning at the supervisory level. Do the same thing with each of the five managerial functions. A convenient way to do this is that you list on the left-hand side the executive and on the right-hand side the supervisory connotations of those functions.

CASES

16-1. J. P. Borden and Company

The Company manufactures popular-priced prefabricated houses. Since the residential housing market has been pretty much saturated since the peak year of 1959, J. P. Borden and Company found it necessary to lower prices even below the present offerings ranging from $2000 to $10,000 (excluding land). To lower prices, a severe cost reduction program will be instituted. The key to cost reduction will be the company foremen. For this specific reason, help was, first of all, given to foremen by acquiring the services of a Midwestern consulting house. The consulting firm, familiar with prefab production, made production standards available so that company foremen nowadays have a precise knowledge of what constitutes a "good day's work." In the recent past foremen themselves determined the output requirement for their men, and, as was to be expected, there was a great discrepancy between the standard and the actual performance; consequently, the contribution to company profitability made by the various plants belonging to the J. P. Borden and Company varied widely.

The sales office, along with the home office, is located in Atlanta, Georgia, but the various plants of the company are scattered throughout the South. Anywhere the company suspects a sales potential, a new plant is established (housed in one of its own prefabricated buildings) and a general manager is appointed to run the plant. In other words, J. P. Borden and Company was operated similarly to a chain of stores.

Because of the still sluggish sales throughout 1961 (even though the company had somewhat recovered from the recession year of 1960), it was necessary not only to cut costs and prices, but, at the same time, to raise building quality. This, of course, had the direct effect of raising, rather than lowering, manufacturing costs. Nevertheless, in order to attract new residential customers, it was necessary to offer, in addition to price concessions, such extras as sliding glass walls, wood paneling, mirror walls, second-level sundecks, and cathedral ceilings. Although to lower manufacturing costs, large-scale operations seemed desirable, the fact that plant size had to be kept as small as was consistent with the absorption capacity of the local market, made it almost impossible to operate high-speed production lines. Instead, building parts were manufactured in economic lot quantities. Departmental foremen were responsible for turning out production in accordance with the requirements of the market. The reason for remaining small in each locality lies in the fact that profit margins were so small as to make long-haul transportation impossible. Hence, plants had to remain as small as the local market warranted. Unsuccessful attempts in different plants to set up production lines revealed that the disadvantages associated with such operation far overweighed the advantages which the line system offered as far as control over employee performance was concerned. All plants are laid out, according to a uniform plan, into departments. From each part an economic lot was completed before another lot (a different lot) from another section of a prefab home was to begin. The whole lot went from department to department until it was completed. Each month, the required number of prefabs was completed. Shipment took place always at the end of the month. During the month, manufacturing and packaging took place, but shipment could not be made until all "parts" which made up a prefab home were available. According to production plans, a certain amount of work load was assigned to each foreman based on current sales. Foremen had to accomplish the work load assignments in such a manner as to finish each "part" of a building within 20 days. Foremen were considered good if they performed all work without overtime pay. It should be understood that, during the month, there were no completed "buildings" available in a sense that all parts of a unit would have been ready. By the end of the month, however, each part belonging to a building became available.

As a result of the availability of time study data on the various operations, (that is, standard work performed on standard parts), the central production control department intends from now on to determine the production schedule for each plant. With this arrangement, the company hopes to reduce manufacturing costs by 25% or more. The work of making a building will be centrally controlled and work will be so allocated that the plant which has the lower hauling costs from plant to construction site[3] will do the work. At times, of course, exceptions might be made and a plant might have to be assigned work despite the fact that it lies farther away from the site than another one, but this will be done only if a given plant is overloaded with work whereas another is relatively underloaded. The principal aim of this new production system is to add 5% to the current paper-thin profit margins and to permit a 10% to 20% reduction in price. Particularly in the sale of shell homes—only roof and sidewalls—might a price concession attract new business. Furthermore, by having 25% more profit margin to play with, the company hopes to increase by 50 miles the radius of the market around each plant. Although in the latter case, a part of the profit margin would be absorbed by added freight costs, it is expected that total sales and profits would still rise.

At this point, however, the above plans are not yet in effect. As of today foremen are merely informed about output standards and it still is up to them to get a good day's work out of their men. At the present time, however, they are not directed from the central production control office. When such arrangement becomes effective will largely depend on some months of experience with the present system of reliance on the judgment of plant managers and their foremen. A better output is expected as a result of informing operating personnel as to what is considered a good day's production of Z-77 sidewalls, T-22 roofs, and so forth.

In order to illustrate the necessity for the new arrangement, let us relate how each plant has been operating under the present system—without the availability of time study data. If a plant has orders to build 100 homes but its monthly capacity is only 80, it can backlog 20 orders. (The latter would be delivered in the following month.) But, if the situation turns out to be similar in the next few months, backlogging becomes impossible. Thus, work has to be accomplished as contracted; the additional 20 homes have to be produced through overtime work or through the output attainable as a result of greater production efficiency in the respective plant. Although some plants could handle 30% more work than rated capacity, most plants currently operate at less than 80% efficiency. This, of course, means that more profit could have been realized had all plants been operated at 100% of rated capacity.

Plant managers were informed about sales, and in turn, they informed their operating foremen about orders which were booked. Each plant had four or five foremen, and they established production schedules among themselves during daily meetings. Each foreman agreed to complete a number of lots during the day. Although these schedules were not perfect, the various plants operated well under this system. However, owing to the fact that in the future operation times will be known, this system will presumably be improved upon.

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[3] While parts are manufactured in the plant, the assembly must, of necessity, be made on the building site.

Questions. The student should be reminded that his main concern in this case is to judge prevailing supervision in this company. The mainstay of operations in the J. P. Borden and Company, apparently, is the departmental supervisor. It is conceivable that by resolving certain inconsistencies, the problem of low profit margins on homes might be remedied simultaneously with the solution of the supervisory problem. Nevertheless, the student should consider only the supervisory problem.

1. What are the symptoms that indicate that this company does not operate as efficiently as it should?
2. On the basis of your findings, conclude what the causes for these symptoms are.
3. Do you think that the information relative to performance standards will automatically effect an increase in efficiency in the various plants? Regardless of your reply, give specific reasons in support of your opinion.
4. Do you agree with management's approach, that is, setting up a centralized control department to improve on the present system of production control?
5. How should the home office strengthen and further implement its contemplated action?
6. What is your opinion about the suitability of the presently decentralized production control at the J. P. Borden and Company?

16-2. THOMSON AND PICCASSO, INC.

The company is engaged in the manufacture and assembly of electrical devices. In normal times, it has 1500 employees. Approximately 50% of all employees are women who could be considered semiskilled; the rest are men. The latter group splits approximately in two halves. The first, and most important, group is made up of skilled machine operators; the other group is mainly of unskilled or semiskilled utility men (machine operator helpers, second-class machine operators, and material handlers).

The company is divided into three departments: assembly, machine shop, and plant services (shipping, receiving, maintenance, storage, traffic, and materials handling). Our concern is the machine shop, headed by Mr. Crome. Mr. Crome, as well as all other superintendents, has several foremen working for him. Since there are no staff departments at T & P, every foreman is responsible for both quality and quantity of output, for inspection, for routing and scheduling, and, of course, for the actual supervising of their subordinates. Hiring is done by the superintendents, however, and not by the foremen. Actually, it consists of a quick interview. For example, Mr. Crome, the machine shop superintendent, asks a few tricky questions of the applicant to determine whether or not he really is the type of machine operator he claims he is. Otherwise, Mr. Crome hires any qualified men regardless of color, creed, or religion. Discharge is, however, in the hands of the foremen, as are remedial transfers, promotions, and pay boosts. When a machine shop foreman requests help, Mr. Crome calls on the State Employment Service by stating the type of help needed. The company's main requirement is, of course, job qualification in the case of skilled mechanics and finger dexterity in the case of semiskilled help. The latter is usually tested by the State Employment Service.

Mr. Crome arrives in the plant at least an hour ahead of everybody else. He sits in his office and plans the daily production runs. By the time his foremen begin to arrive at 7:50 he has already developed the daily production plans and is eager to get on with the morning strategy conference. Here, speaking in a fast sputter, he tosses off his instructions as an emery wheel tosses off sparks. Although he lets his foremen run things, he is always available for consultation. He spends the day in his office working on various projects.

At 10 A.M. one day last spring one of Mr. Crome's foremen knocked at his door to discuss a problem he did not know how to solve. The problem was an employee, Bill Zaborski, whom he wanted to transfer to another department. The difficulty was that no other department wanted him. Thus, Zaborski had to be fired, but, of course, firing a man is a serious matter. That is what the foreman wanted to talk over with Mr. Crome. He also considered a layoff, a sort of a terminal layoff, but Zaborski had seniority over other men the foreman wanted to keep.

The foreman read the following information about Zaborski from a piece of paper: "Zaborski, employed by us since 1955, has been laid off many times. He came to the company as a common labor, but worked his way up to machine operator B. He is 45 years of age, is married, and has four children still in school. Although he has no record of poor workmanship or misbehavior, he requires too much supervision and even then he is usually unable to accomplish the assignment within the allowed time. Otherwise he is friendly, cooperative, takes any kind of assignment in good spirit. Based on general observation, he seems to do his best, but just cannot produce as required. Zaborski was hired by Mr. Crome."

Foreman Murphy said to Mr. Crome, "I can do one of two things—fire him or transfer him. But I have not found anybody who would take him off my hands. Everybody says that they wonder why I kept him that long."

"Why did you keep him for so many years?" asked Mr. Crome.

"Well, back in 1955 he was the union steward and replaced JJ who died at the time. He held that job until the new election, when he was voted out. At the time, however, he still earned $1.25 an hour and at that rate, he could be used on several jobs where the profit margin was pretty reasonable.

But, today, I cannot put him on any job; we don't seem to have any more jobs with high enough profit margins. Then again, in the meantime he earned seniority rights, one of the highest in the company. Today, I can't even lay him off, except after everybody else. Thus, I'm really stuck with him."

"Let me talk to Mr. Schneider," suggested Mr. Crome. "If we can transfer him to the assembly department, the problem will be solved."

A couple of days later, during the lunch hour, the conversation continued as follows: "I spoke to Schneider," said Mr. Crome, "and he said that unless you find a foreman among his men who would take him, he is not willing to transfer him to his department."

"Then, I won't do anything for the time being," said Mr. Murphy, "because I know that nobody will accept him."

"What do you plan to do?"

"I don't know yet; I only know that I cannot take the risk of demoting or firing him because the labor union will be down on our necks. Zaborski has a lot of friends in the labor union as well as among the men in the shop. If I fire him, the boys in the shop will gang up on me and I won't be able to get work out of them. On the other hand, the labor union won't agree, I presume, with the discharge of Zaborski and will go to bat for him until I would rehire him with a possible back pay. Oh well, something will happen! And I have an idea how."

"And what is your idea," asked Mr. Crome.

"Do you need a new foreman?" asked Murphy. "I believe he would make a fairly good foreman; he has a lot of friends; he can tell things to the boys and they will listen; he has a pretty good comprehension about every job in the shop; he can run many machines. But he is so darn slow that nobody can use him at a time when we have to pinch pennies."

Questions. Obviously the case has not ended here, but the decision must be made so that it is a permanent one, that is, without repercussion from the labor union, without hardship to Mr. Zaborski, and in the best interest of the company.

1. If you were Mr. Murphy, what would you do and why?
2. If you were Mr. Crome, how would you handle Mr. Murphy and how would you judge Mr. Murphy's ability as a foreman?
3. If you knew that Bill Zaborski now made $2.15 an hour, how would you handle the situation?
4. If you knew that on the assembly line or in the subassembly departments only girls who made anywhere from $1.30 to $1.60 were employed, would you have even considered a transfer?
5. Let us assume that there is an opening in the machine shop for a foreman. Would you consider Mr. Zaborski for the opening?
6. Who would you blame for the problem, Mr. Crome, who hired Zaborski, or Mr. Murphy, who retained Zaborski for so many years?

16-3. Barr and Stimpto, Inc.[4]

Foremen of the forge shop at Barr and Stimpto, Inc. had considerable difficulties with the Independent Forge Workers Union representing the company's employees. The problem started a few years ago after a local of the AFL-CIO made an unsuccessful attempt to organize the employees of the company. Although a vote prevented the AFL-CIO from organizing the plant, an independent union was formed to duly represent the forge shop's employees. Some of the strikers at the time of the above-mentioned difficulties were not satisfied with the new arrangement, but, of course, returned to work. Ever since this happened, they have been making trouble for the company, and particularly for the foremen.

Although the company would have been better off without those employees who instigated the strike a few years ago (it lasted 116 days), the agreement between the Independent Forge Workers Union and the Company provided guaranteees that everybody would be recalled at the time operations resumed. The company kept its part of the bargain, but some of the "pioneers" were constantly at war with the company. Actually, it was not the union which was so troublesome, but a "few union members." These union members were extremely hard to deal with and had to be handled with kid gloves by their respective foremen. Because of the original guarantee that the company would not discriminate against any union member because of union activities, these men felt safe in their jobs, but they were particularly happy if they could harrass the foremen and the company.

Several appropriate paragraphs of the labor contract are quoted here to illustrate the delicacy of the problems with which one of the foremen has wrestled during the past week:

Article I, Section 3

The Company agrees that no foreman, or working foreman, shall be called upon to perform any of the duties of the employees covered by this agreement either for production purposes or rate setting, except working foreman may continue as it has been the practice and others may do production type of work in emergency. The union steward will be given the reason for the emergency.

Article VI, Section 1

The Company agrees to recognize and meet with shop stewards and/or officers of the Union or its authorized agents as official representatives of the Union in all matters that may arise between the Company and the Union and either during or immediately after the normal work day.

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[4] This company name, as many others used in this book, is fictitious. Although the company and its problem or problems as presented in this and any other previous case, were real, a fictitious name was used to preserve the anonymity of the company, unless management permitted identification of the true corporate name. The location, size, and the dollar volume of business of a company, and occasionally even the product it made, were changed to disguise its true identity. Thus any resemblance to persons, situations, and any other characterizations which may in any form or manner be embarrassing to a given company is purely coincidental.

Article VII, Section 1

Any employee who believes that he has been unjustly dealt with shall have the right to have his grievance settled in the following manner and order.

(a) In the first instance, between the grieved employee and his foreman, the interested department steward may be asked by either party to participate in the discussion for the purpose of aiding in the handling and adjustment of such grievance, or at the request of the agrieved employee the interested department steward may handle the adjustment of such grievance for the employee;

(b) In the event that the complaint is not adjusted within two hours by the foreman, it shall be presented to the Department Head for adjustment;

(c) If not adjusted by the Department Head within 24 hours after being presented to him and in any event within 48 hours, it shall be submitted in writing on official grievance forms by the employee to the Works Manager, and the Works Manager shall file the complaint and answer within one working day with the Director of Industrial Relations, who shall present the complaint and answer within the next 24 hours at a meeting of the bargaining committee.

(d) If not adjusted within the next 48 hours, or continued by agreement, the matter may be submitted to arbitration as hereafter provided.

Article X, Section 6

Short run jobs shall be paid at the piece work rate or tryout time, whichever is the greater. (What constitutes a short run job will be mutually determined by Labor and Management.)

Article XVII, Loss of Seniority

An employee shall lose any and all seniority rights if

(a) He quits.

(b) He is discharged for cause.

(c) He is absent for three consecutive working days without notification to his foreman within three days after the expiration of such leave.

On July 17, just as Mr. Johnson, a foreman in the drop forge department, was ready to call it a day, he noticed that a message was coming through the telautograph used by the shop and production planning department to communicate with one another. The message read:

FOREMAN JOHNSON, HOLD OVER TO THE NEXT SHIFT ONE OF YOUR HAMMERMEN AND HAMMER HEATERS UNTIL PETE CHOATE AND BOB RAZNIAK FROM THE SECOND SHIFT ARRIVE. IT MIGHT TAKE AN HOUR, BUT AT MOST TWO HOURS. THESE MEN JUST TELEPHONED THAT THEY ARE INVOLVED IN AN ACCIDENT AND HAVE TO WAIT UNTIL POLICE ARRIVES. THEY ARE ALL RIGHT AND WILL BE AT WORK AS SOON AS THEY CAN. NOTIFY ALSO RESPECTIVE SECOND SHIFT FOREMAN. CONTINUE WORK WITH DROP HAMMER 7 ON THAT RUSH JOB FOR THE GOVERNMENT TO BE SHIPPED TOMORROW MORNING.

After reading this message, Mr. Johnson ran into the dressing room, then to the gate where employees leave the plant. He did not see any one of the men who could have been used on this job. He was looking for Red Pivak and Ed Molnar, who were regularly assigned to drop hammer 7 and had the first claim on overtime work. However, he did not see anybody who was qualified to run the drop hammer. He even asked one of the workers who was walking toward the parking lot to send in Pivak and Molnar if he saw them. "Tell them," foreman Johnson said, "that I have to hold them over for an hour or two with overtime pay." On his way back, foreman Johnson looked into the shower room where he saw Ed Molnar, the hammer heater. Foreman Johnson said to him: "Ed, am I glad to see that you are still here. Do us a favor. Stay another hour or so on overtime until Pete Choate on the second shift arrives and replaces you. But please hurry—we cannot lose a minute of production time on that drop hammer 7, otherwise we really won't be able to ship that government job tomorrow morning." Ed Molnar said OK and returned to the drop forge department where the second shift had already begun to work. Only a few minutes must have been lost on drop hammer 7.

Since time was the essence of shipment, Johnson did not hesitate to operate the machine himself. Since there was nobody around who could have been assigned to the hammerman's job, it was necessary that he take over until Bob Razniak arrived. When, a half hour later, the second shift foreman arrived, he wanted to know why Johnson was running the drop hammer. Immediately thereafter, the second shift foreman left with the intention of seeing the union steward to tell him about the emergency and that Johnson had to run the machine in order to save valuable machine time. But the shop steward was not found until another half hour later, just at the moment that Pete Choate and Bob Razniak reported to work. Ed Molnar had already disappeared.

Although the second shift worked regularly, the shipment was delayed because 45 pieces were still missing and had to be finished during the following morning. Foreman Johnson was so busy on that morning that he did not know what to do. The expeditor, the superintendent, and others were asking when shipment could be made. The government sent a plane down to the airport to pick up the pieces and take them to the missile base in Florida. At any rate, to make the shipment it was necessary to set up another drop hammer and foreman Johnson was doing dozens of things, including instructing millwrights and maintenance men about the nature of setup. As this was going on, foreman Johnson took a look at drop hammer 7 where Red Pivak was supposed to work on the urgent job. Instead, he was standing in front of the coffee machine and talking to the shop steward. Mr. Johnson excitedly said to Pivak: "Red, we have a rush job and you and your pals are wasting time. You guys have no sense. You better get back to your machine or I'll really do something about it. And make sure that I get at least 20 pieces by 9 o'clock."

Hammerman Red Pivak replied, however, "Mr. Johnson, we have a little business to straighten out first."

Johnson: "Never mind anything now, go back to your machine and work like hell. I don't want you to waste a minute more until this job is closed out."

July 18 as well as 19 were hectic days for Johnson. One rush job after the other had to leave his department and he was giving orders right and left. He encountered Pivak on July 19 when his drop hammer supposedly broke down. Because the shop was busy, Johnson called the repair crew immediately. The crew claimed that the machine was deliberately jammed. Since business was good, and everybody was needed, Johnson assigned Pivak on a fill-in job. Pivak argued about the rate he was going to get on the job. "You get your normal pay," said Johnson, "It's not good enough," said Pivak.

At the end of July 19, which happened to be a Friday, Mr. Red Pivak found the following note in his pay envelope: "This is to notify you that your services are no longer needed after August 5. Please call at the personnel department to take care of your records."

Just before closing time, the telautograph wrote out the following note to foreman Johnson: "Mr. Johnson, see Mr. Knots, [the works manager] as soon as you become free at the end of your shift."

In Mr. Knots' office was Mr. Mulligan, the shop superintendent, Mr. Johnson's boss. As he entered, the following conversation started.

"Look, Tom," Mr. Milligan said, pointing to an official grievance lying on Mr. Knots' desk, "the union claims that you did not settle an argument over overtime work which you performed instead of asking Pivak on July the 17th. Is this true?"

At that point Mr. Johnson explained the problem he had and the nature of the emergency. "You know, Pivak is one of the men who fought for the AFL-CIO accreditation and he cannot reconcile himself to the fact that they did not win the strike. Ever since, he's been giving me a hard time. I understand that the union promised him the position of shop steward in case they got in. I suppose he wanted to run the shop with me."

Mr. Milligan: "What you think we can do?"

Mr. Johnson: "I guess this is not the end of this anyhow. I just fired Pivak for insubordination. And he jammed his machine this morning. I suppose even if he fights us through his union, both problems can be settled at the same time."

When Mr. Johnson left, Mr. Knots turned to Mr. Milligan and said, "This Johnson should have settled the argument right then and there."

Mr. Milligan: "Johnson is a good man, and if he did not, there is certainly a misunderstanding. The chances are he was so eager to get on with that government job that he did not hear exactly what Pivak and the steward had in mind."

Mr. Knots: "What are you going to do about the firing of Pivak?"

Mr. Milligan: "I don't know. I guess we will have to call the union's business agent and explain this whole thing to him. Probably we can avoid an arbitrator. I guess I can settle it. But, this darn thing will tie me down for quite a few hours. I am sorry that you're in it too. But, you can't blame Johnson, he has a bunch of rough guys to deal with! Well, I'll call the business agent tomorrow and probably we will get an agreement on the grievance and on Pivak's discharge. I'll let you know."

Questions. The case does not end here, but for the purposes intended we have covered the foreman's part in labor problems. The case indicates how important it is that the foreman be aware of the various paragraphs of the labor contract. It is apparent also that to succeed in first-line supervision, it is essential to act always in accordance with the labor contract.

1. Did Mr. Johnson make an obvious mistake as a supervisor?

2. If you were foreman Johnson, how would you have handled the situation?

3. Put yourself in foreman Johnson's shoes (the pressure of the job, the shipment which must be made, and the importance of the contract) and state how he could have avoided conflict with Pivak in the first instance. How did he behave in the case of the wage rate argument on short-run jobs and what should he have done prior to firing him?

appendix A

Profit, Profitability, and Productivity

Every intelligent citizen recognizes the need for profit from his own endeavors. Even a famous labor leader once remarked that the worst crime against working people is to fail to operate at a profit. When most companies have trouble covering their expenses with something to spare, the shrinkage in job opportunities and wastage of manpower and productive capacity become all too obvious. For this reason, any deterioration in corporate earnings is a critical matter; it strikes at the very heart of the capitalistic economic order. In a free-enterprise system, the motivating force to take risks is profit. If profits cannot be maintained at reasonable levels, progress toward a higher standard of living will be slowed down. Thus, profit is the key to economic growth and, simultaneously, the lubricant of the wheels of production.

Since economic growth expressed as a change in national productivity is a desirable goal, the questions arise as to how it can be attained and how management can help to maintain it at a high level.

PROFIT

Profit is the residual after the costs of production, including distribution costs, are met. The greater is this residuum, the better is profitability, and by the same token, the efficiency of an enterprise. Thus, management must aim at enhancing profits. In a competitive world, however, profits are under constant pressure because the competitive forces on the marketplace force price fluctuations. If costs are rising and in many instances prices are depressed, there is a tendency to squeeze out profits. This can be bad for the economy, because it tends in certain segments of the economy, anyway, to affect national output. Let us consider this relationship.

In fields where large capital investment is necessary to enhance the output per man-hour, such as in the chemical and steel industries, a decline in the rate of profits would start a vicious cycle because it would block the flow of capital where it is most needed since investment usually declines in low-profit areas. Lack of replacement or improvement of capital will precipitate falling productivity of the enterprise and may sooner or later cause further deterioration of profitability. Thus, without profits, neither capital improvement nor technical efficiency can be attained.

Since national productivity is a composite of individual company and industry wide productivities, when the general level of profits fall, the chances are that the productivity of the economy will also slow down. When this happens, the standard of living stops rising, or rises at a slower than desirable rate. This reduces job opportunities, and the growth of population brings about a rise in unemployed resources. Under these circumstances, if productivity of the economy as a whole increases, it simply means that more goods are being produced with fewer man-hours of labor than before. The changes which take place year after year in the man-hours needed to produce a given amount of goods in dollar value is what we call national productivity.

Thus, both from the national and the company points of view, a growth of productivity per man-hour of labor and profitability are important. Despite the significance of rises in productivity and/or productive efficiency, a great deal of misunderstanding exists about the function of profit, and in some quarters profit is regarded as something undesirable. It goes without saying that this view is completely out of place in a free-enterprise economy because the very foundation of the system is attacked.

Whether an enterprise is successful or not can be measured in profits or in costs. The latter refers to the use of the resources *per se*; the former, to the use of resources in respect to market conditions. For an individual enterprise both are important. To the economy as a whole, the efficiency with which the resources are converted into the commodities and services that people want is of basic importance. We live in a society where our welfare and economic progress are influenced by, and at the same time our individual efforts tend to influence, the status of the economy. Thus, each enterprise contributes to the health of the economy, but in turn, economic health is reflected in the profitability of business.

PITFALLS OF MEASUREMENT

Since productivity is the ratio of the value of output, or the results of production, to the corresponding value of input of economic resources, both during a given period of time, the problem of how they can be measured arises. It is obviously difficult to measure these factors, because no one reports input and output figures to a central place (except when declaring income taxes and giving overall employment and unemployment figures). Because of scarcity of information, the productivity increases are expressed in man-hours needed to produce a given amount of goods. The value of all goods produced is a way of stating national income and is expressed roughly in the gross national product. This figure, in turn, must be reduced by capital consumption allowances (including depreciation) to arrive at the net national product, which is a measure of current net output. That this measurement emphasizes the contribution of labor to national productivity is a coincidence; nevertheless, it creates an impression that productivity increases should be credited to the added diligence and skill of labor. And, of course, nothing can be farther from the truth.

PRODUCTIVITY OF LABOR

The productivity of labor is merely a measuring device, and a poor one at that, indicating the changes in man-hour requirements to attain given results. Labor is not the sole contributor to the changes in output per man-hour (in fact it often resists capital improvement which would increase labor productivity). Its measure reflects the operation of many factors, such as changes in technology, equipment, capital investment per worker, utilization of plant capacity, layout and the flow of materials and managerial skill. Bulletin 1249 of the Bureau of Labor Statistics of the United States Department of Commerce states in general: "Although the measure relates output to man-hours, it should not be interpreted to represent the unique contribution of labor to production." Apparently the operation of many factors, some of them not readily measurable, such as improvements in quality, improvements resulting from better utilization of capital and manpower resources, the disregard for the many hours incorporated in purchased materials and tools of production or the increased costs of machines or materials that precipitated the higher output, must be included to give a clear-cut and perfect picture. Since all the above are measurable only by the common denominator of money, everything must be reduced to monetary terms. The difficulty again is that monetary units do not remain stable but are subject to changes in relative value. Furthermore, the same monetary common denominator is inadequate when it comes to the measurement of the output, mainly because there is no specific price index which would measure the changes for rent, capital, and other contributing factors of production. For this reason, it is an almost insoluble problem to relate the contribution of each factor to the changes in national productivity.

Table 1-1, page 9, indicates that on the average, the productivity increases amounted to 2% per year. However, if measurements could be found, as already suggested by Professor Kendrick, capable of specifying the contribution of all factors of production to the efficiency of national production, the 2% productivity factor currently indicated would certainly be deflated. As a matter of fact, the annual rate of change in productivity based on the period of 1889 to 1953 has been estimated by Kendrick to be only 1.7%.[1]

Since the problem of productivity interpretations seems to lie in measurement, not in what it implies in terms of business and the country's manage-

[1] John W. Kendrick, "Productivity Trends in the United States," *Annual Report*, National Bureau of Economic Research, 1962.

ment, productivity measures are not necessarily the best means of showing national progress or deterioration. The problem, however, is not whether the statistics are right or wrong, but whether the data present an accurate enough picture of the economy at any given time.

THE PROFIT SQUEEZE

Barring competitive damages firms may inflict upon each other, it is apparent that the efficient—and profitable—plant contributes most to the productivity of the economy. Hence, the decline in the rate of corporate profits and profits in general which took place in recent years[2] should be treated with alarm rather than as a sign of industrial competitiveness and economic health. If the failure to maintain profitability were due to lack of managerial talent to organize the resources economically, no one would be concerned with the lack of profitability. The trouble, which businessmen in general appear to think, is that the decline is largely attributable to fiscal policies of the government, particularly that regarding corporate taxation.

There are two particular problems affecting profitability over which business cannot exercise control: 1) corporate profit taxation and 2) depreciation allowances for wornout equipment. Yet, these two important factors tend to influence profitability of individual enterprises and the productivity of the nation as a whole. In the first instance, double taxation (taxing corporate profits at a steep rate of 50%, or above, and taxing dividends again when they become income) deserves mention. In the second instance, the inadequacy of depreciation allowances deserves serious thought. When the company is not permitted to depreciate its facilities at the same rate with which they wear out by technology or obsolescence, any investment in replacement and rejuvenation of obsolete equipment must be made at the expense of profits. When one draws on profits to make the necessary reinvestment because it is not considered a necessary cost of doing business, the tax tends to penalize success and thereby slows down the growth and the health of the economy as a whole. Quite recently, however, there has been some effort to alleviate this problem. Whether this is *the* answer, remains to be seen.

MEASURES OF PROFITABILITY

The natural measure of profitability is the number of dollars of net profit earned, but the size of the profit should be looked upon in light of what it took to earn it. It tends to be overlooked that in some companies the huge capital investment per worker is the factor which enables him to work efficiently. In some industries, the per capita (per worker) investment in equipment and facilities amounts to anywhere from $10,000 to $100,000. Therefore, the size of profit as such is meaningless without considering the capital investment.

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[2] While in the decade 1950-1960 the GNP increased by almost 75%, the total of all corporate profits (after taxes) remained at the level of the previous decade and they show currently further declines. All of the profits after taxes earned by all corporations in the United States in 1962—including profits reinvested as well as profits paid out to shareholders—did not equal the fringe benefits paid on behalf of employees. Moreover, profits have been actually declining during the past 8 to 12 years, whether measured as a percentage of stockholders' equity, of sales, or of national income. In terms of the last, after-tax profits have gone down 41% in 15 years, while the share of national income going to compensation of employees has risen 9%. During the same time, consumer spending rose 104% and government spending, 279%.

Generally speaking, profit can be related to the invested capital, that is, the return on investment, on the one hand and to sales, that is, return on sales, on the other. Furthermore, it is essential to speak always in constant dollar values. Unless both investment and profit are restated to account for inflationary changes over the years, comparative data become meaningless. Comparative data are meaningless also when a capital-oriented plant is contrasted with a labor-oriented plant in the sense that the cost structure is based on entirely different foundations. On this basis, the capital-oriented plant must, of necessity, earn considerably more to be considered healthy than the labor-oriented plant.

appendix B

Statistical Quality Control

Because Chapter 6 made reference to statistical quality control, additional details are warranted. It should be emphasized, however, that this book deals primarily with quantitative control over production and deals with qualitative control only to the extent that an alarming rise of the reject rate could have serious effects on quantitative control also. More units would have to be scheduled for production and more time on the machine would be needed to accomplish the required output quantity than otherwise would have been necessary. For this reason, a minimum amount of acquaintance with statistical quality control is warranted. That the subject matter cannot be covered adequately in a few pages becomes apparent when one considers that an outstanding book[1] on the subject is some 700 pages long. Quality control is a statistical skill, and a book, not an appendix, is required. Here it is only possible to sketch a brief outline.

This material should rightfully be mentioned under one of the mass production chapters dealing with repetitive, continuous, and automated production, because in intermittent production seldom, if ever, is statistical quality control applicable. To replace 100% control with statistical sampling, large volumes of goods must be involved; otherwise 100% control is just as cheap.

The idea behind statistical quality control is that if perfection is difficult and costly to attain, one must be satisfied with imperfect production as long as it falls within certain quality limits. Although each item will differ slightly from all other items, probability theory tells us that these variations will follow a pattern. And, if there is a pattern, it can be measured and controlled; see the concept of frequency distribution in the following diagrams.

Prior to control, the characteristics of quality must be found in terms of amperage, size, weight, color, elasticity, hardness, dimension, etc. After knowing what we are looking for in terms of quality, the questions are how much variation is permissible and to what extent can variability be placed under control without undue cost and effort. In other words, which is cheaper: to have rejects or to prevent rejects from being manufactured? (It costs just as much to produce a defective workpiece as an acceptable one.) Actually, what we want is to set boundaries around these variations, and if the variations start crossing the boundaries, whether upper or lower, to do something to bring quality back to normal.

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[1] Dudley J. Cowden, *Statistical Methods in Quality Control* (New York: Prentice-Hall, Inc., 1957).

When statistical quality control is practiced, samples are collected, and based on them, one infers whether quality meets some specified standard.

Depending on the nature of production, control can be attained in two different ways 1) through process control and 2) through lot control. The former is preventive, the latter informative in character. In process control, samples taken during the course of operation will, after being measured and plotted on a control chart, reveal whether the operation in question is getting out of control. In lot control, the samples are taken after the lot (batch) is completed. If the quality fluctuations fall within the boundaries considered normal, the lot is accepted. If some still fall outside these boundaries, the question is what percentage of the total is the reject. A given percentage of undersized or oversized pieces (or whatever the qualitative criteria) is still considered qualitatively acceptable. The vendor and buyer merely agree on the permissibility of a given percentage of defective pieces in the lot. A random sampling of the lot before shipment, and then inspecting and recording the variations among the sampled units, will reveal whether the lot as a whole is acceptable or must be rejected. If the percentage of reject in the sample is greater than the expected reject factor, then, according to the probability theory, the chances are indeed that there are also more bad pieces in the lot than is permissible.

PROCESS CONTROL

In continuous production, it is important to catch faulty production before the seriousness of the error becomes so great that the workpiece must ultimately be rejected. Before real trouble develops, operations must be stopped and causative factors eliminated. This can be done via control charts which are constructed on the basis of elaborate mathematical calculations.

Variations in quality are measured both in terms of chance variations inherent in the process or the raw material and variations attributable to assignable causes. About the former nothing can be done, because, for instance, no manufacturer can control the chemical characteristics of a metal (for example, hard spots) purchased from a steel mill. Thus, the characteristics of the metal may precipitate its becoming a defective workpiece. About normal variations, however, something can be done. If variations are within reasonable limits, there is no need to do anything about them; if they tend to go beyond predetermined limits, they must be brought back to normal. The control chart will reveal departure from normal just as the heat gage on an automobile dashboard indicates motor overheating. Thus, statistical quality control aims to establish control limits which supposedly strike an economical balance between chance variations and variations due to assignable causes. A control chart, about which more will be said later, may look something like that in Fig. B-1. As production proceeds, random samples of appropriate size are taken from the currently produced units and are carefully inspected for

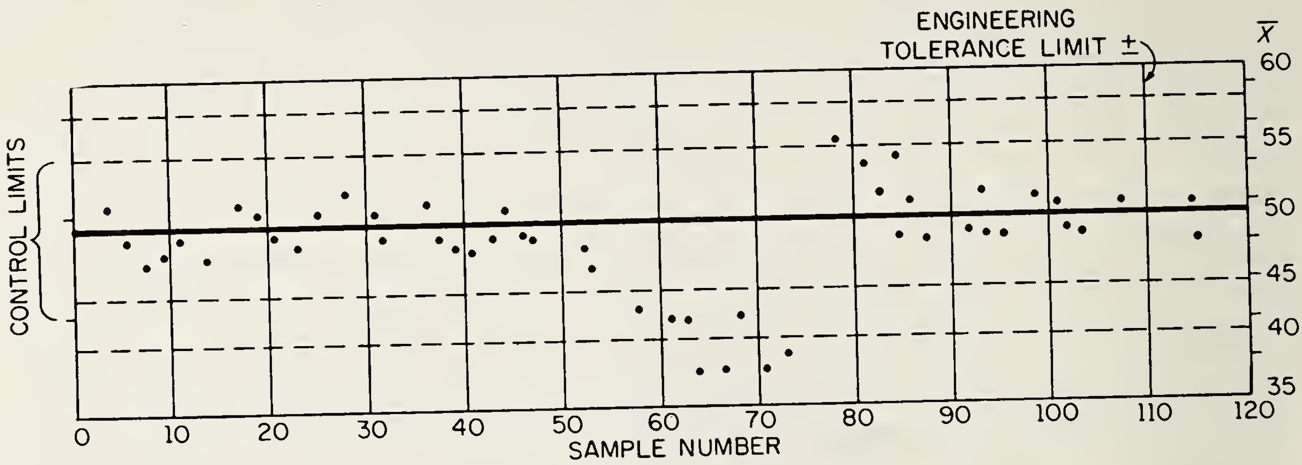


Fig. B-1. Control chart.

quality characteristics. The measurements of the quality are then plotted on the control chart. When there is a downward or upward tendency (see the chart), one might suspect impending trouble. A causative factor in a machine shop might be the wearing out (dulling) of tools.

LOT CONTROL

The computational procedure in lot control is the same, except that no control chart is used and samples may be taken after an operation is completed instead of during it. Otherwise, limits that separate normal from abnormal variations are established. The random samples taken must fall within established quality standards. If they fall beyond normal limits more often than permissible, in other words, if there is an excessive number of defective pieces in the lot, the lot as a whole may be rejected under the statistical probability that in the lot as a whole more than the normal amount of rejects will be found.

One makes an agreement, for example, that there should not be more than 5% reject in the lot. The sample must prove that indeed there is not more than 5% reject (excluding the normal variations) in the lot. Although defectives are in the lot, the assumption is that even a 100% inspection would not be able to catch all of them. As long as it is known that the probable number of defective pieces in the lot is within the agreed percentage, both the vendor and the purchaser are satisfied.

THE MATHEMATICS OF CONTROL

To control quality by statistical means, the following factors must be determined through mathematical calculations:

1. The number, randomness, and size of the samples to be taken
2. The statistical average of samples ($\overline{X}$ = mean)
3. The permissible deviation from the mean, that is, upper and lower control (confidence) limits
4. The control chart (only in the so-called process control)

Now, the size of the sample must be adequate for the purpose because it will influence the accuracy, that is, the results desired. Apparently, a large number of samples will probably predict the quality characteristics of the output as a whole with a greater degree of accuracy than a relatively small number of samples. The randomness of the sample is of equal importance, particularly if the control chart is based on the variation range rather than standard deviation principle. (For sample size, see page 277.)

The samples collected will be studied in light of the qualitative attributes (for example, diameter) and the results will be recorded. If expressed in diameter, the exact dimension of the sample pieces will be written down. Since no two output units are identical, the deviation from one another will help to determine the *average*. Although this computation will be pretty close to being correct, the sample size has a lot to do with possible error in the point of departure from which the control limits are determined. To compensate for such possibility of computational error due to the relative smallness of the sample—under the assumption of normal distribution, that is, a bell-shaped curve—the error may be appraised with the formula

$$\text{Limits of percent defective} = p \pm 3\sqrt{\frac{p(1-p)}{n}}$$

where n = size of sample,
p = percentage secured by dividing number of rejects in sample by size of sample.

Obviously, comparatively small samples will create greater chances for error than larger samples. Therefore, in setting quality control limits based on comparatively small samples, it is well to set the control limits liberally enough to cover chance errors inherent in sampling or make statistical adjustments for small-sample error.

THE PROBABILITY THEORY

Without getting into a complicated explanation, let us define probability as the limiting value of the relative frequency as the number of samples approaches infinity; that is,

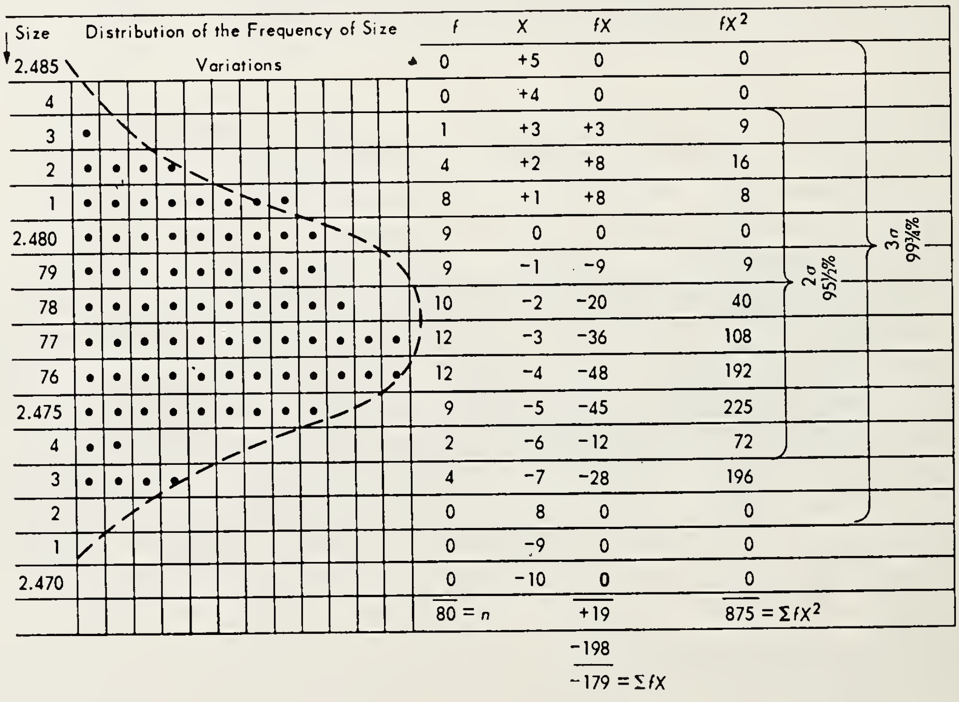
$$p = \lim_{n \to \infty} \frac{m}{n}$$

The letter p denotes the probability of the event whose relative frequency is m/n. To conclude on probable occurrences, the sequence of experiments (in quality control, the number of inspected workpieces) which becomes infinite must be a random sequence. In other words, we must pick and choose systematically. Thus, we select n_1 samples out of n samples in an arbitrary manner. If we were to notice defective pieces (the probability occurrence of which we want to compute) m_1 times among the n_1 samples, then we must have

$$p = \lim_{n_1 \to \infty} \frac{m_1}{n_1}$$

where p represents the probability. Regardless of how many samples we make, the same ratio between samples and frequency of defectives must occur despite raising or lowering the number of samples. Of course the more samples are being made, the greater proof for the validity will be attained.

Although still not rejects, some of the samples will be oversized, some undersized, and some just about right. The list of the quality measurements thus found must now be arranged according to diameter. When plotted on graph paper, the frequencies with which various sizes are found in the sample



Size	f	X	fX	fX²
2.485	0	+5	0	0
4	0	+4	0	0
3	1	+3	+3	9
2	4	+2	+8	16
1	8	+1	+8	8
2.480	9	0	0	0
79	9	−1	−9	9
78	10	−2	−20	40
77	12	−3	−36	108
76	12	−4	−48	192
2.475	9	−5	−45	225
4	2	−6	−12	72
3	4	−7	−28	196
2	0	8	0	0
1	0	−9	0	0
2.470	0	−10	0	0
	80 = n		+19 −198 −179 = ΣfX	875 = ΣfX²

$$\sigma = \sqrt{\frac{\Sigma fX^2}{n} - \bar{X}^2}$$

$$= \sqrt{10.94 - 5.09} \qquad \bar{X} = \frac{\Sigma fX}{n} = \frac{-179}{80} \qquad \frac{\Sigma fX^2}{n} = \frac{875}{80}$$

$$= \sqrt{5.85} \qquad = -2.2375 \qquad = 10.94$$

$$= 2.42 \qquad \bar{X}^2 = 5.09$$

FIG. B-2

will form a curve (see Fig. B-2)[2]. When fitted, the chances are it would look like a normal distribution curve, where the preponderance of sizes would fall in the middle representing the *average diameter* ($\overline{X}$) of the workpieces mathematically:

$$\overline{X} = \frac{\Sigma X}{N}$$

where X = variable (the measurements on the sample pieces),
N = number of samples taken.

STANDARD DEVIATION

Of course, the curve in itself means nothing yet. Variability must be appraised in acceptable engineering standards. The workpieces may be a bit oversized or undersized, but they must still function properly. Thus, it must be ascertained into which range all good workpieces must fall. To do so, the variability of the sampled workpieces from the average $\overline{X}$ must be determined. If the average in the preceding example were 2.480, the question is how far the various sample pieces will deviate from this size and the frequency with which each size appears; mathematically,

$$\sigma = \sqrt{\frac{\Sigma f X^2}{n} - \overline{X}^2}$$

where Σ = the sign of summation,
f = frequency,
X = quality measurements sample by sample,
$\overline{X}$ = average of all sample measurements.

When these differences are multiplied by themselves, the squared differences must be tallied and divided by the number of samples. The square root of the answer is called "standard error." Statisticians have found that by adding and subtracting three standard deviations, 3σ (sigmas), from the mean $\overline{X}$, 99¾ % of all sample values will fall within this range as long as no disturbing factor has "skewed" the curve. Of course, in practice most distribution will be somewhat asymmetrical, but the result of the sample measurements would, when organized, most likely approximate the normal curve. Unless there is strong evidence to the contrary, for practical quality control purposes a normal distribution is assumed. Based on the samples collected, it is possible to establish a midpoint around which the variations will fluctuate, up or down. If we assume that the control chart in Fig. B-1 was based on 3σ limits in either case, up or down, the average, $\overline{X}$, of the various chance variations is the center line. At about the 50th sample, it seems that the process is beginning to get out of control. When this is noticed, appropriate action can bring the process back to normal. Assuming that this is what happened and, say, a dull cutting tool was changed, as of the 80th sample the variation turn-up was on the high side, indicating a sharp tool. Figure B-2 is a computation of the standard error and the sigma limits together with a superimposed curve.

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[2] Source: C. W. Kennedy, *Quality Control Methods* (New York: Prentice-Hall, Inc., 1948), p. 157.

appendix C

Brief Summary of Wage Incentive Plans[1]

As mentioned earlier in the text, wage incentive plans serve the purposes of production scheduling. There are as many different wage incentive plans as there are plants employing them. It would be difficult if not impossible, to state which one would best serve the interest of either management or labor. Even though these plans differ, they have one common aim: to induce workers to produce more without penalizing them, with notable exceptions, for underproduction. It should always be emphasized that no wage incentive plan aims to raise production in the absolute sense; all that any plan can be hoped to do is induce workers to produce the quantity which a "normal" worker can and should produce and the superior man can even surpass. The underlying assumption is that workers do not perform up to par, that is, do what according to the time study they can reasonably be expected to do, primarily because the wage rate received provides no incentive. Since the hourly pay is received whether or not a fair day's work is delivered, a great deal of time tends to be wasted in talking, visiting one another, loafing, and generally being inattentive. Management hopes to eliminate, or at least minimize, this wasted time by the introduction of a wage incentive system.

TAYLOR DIFFERENTIAL PIECE RATE PLAN

To earn incentive pay the employee must under the Taylor plan produce at least the prescribed standard hourly output. The quota is purposely set somewhat below the output requirement which would be warranted by the time standard. Whether this is 10%, 20%, or more depends on managerial decisions.

[1] Some of the examples as presented here will differ from the conventional presentation because an attempt has been made to use a uniform method for every system. The mechanics of wage payment calculations would, of course, differ from the illustrative material particularly where payment is based on the pieces turned out, rather than where hourly payment dominates and bonus is paid on the time-saved principle. For instance, contrast the Taylor differential piece rate plan with the Rowan plan.

For purposes of wage payment, however, there are two rates: 1) high wage rate for those attaining above-standard performance, and 2) low wage rate for those attaining below-standard performance. For the sake of explanation, let us grossly exaggerate the wage rate differential and assume that below-standard performers will receive roughly $1 per hour and above-standard performers will receive roughly $2 per hour. Obviously, it will be in the worker's best interest to work hard on every job he is assigned to meet the standard in order to earn always the higher rate on every job which begins at that point. Of course, the employees are on a piece rate, and if the standard is, say, 60 pieces per hour and the low and high rates are $1.20 and $2.00, respectively, those producing at an output rate of 50 per hour get $0.02 apiece, whereas those making 60 or more units per hour get almost $0.04 apiece. An example is given in the accompanying table.

Worker	Performance* (Expressed as percentage standard of 100%)	Wage Rate	Total Weekly Earnings (40-hr week)
A	200	$2.00	$80+$80=$160
B	150	$2.00	$80+$40=$120
C	100	$2.00	$80 (no bonus)
D	50	$1.20	$48 (no bonus)

* Performance of 200% means that the worker turned out twice as much as the quota called for; 150%, that 50% more than the quota, etc. Evidently the man who turned out 50%, produced only ½ of what he should have produced. Putting it in another way, the man of 50% efficiency needs two hours for one hour of work.

According to the original Taylor plan, the worker performing below standard would have earned one half of $48, since his output was 50% of the standard. However, since most wage incentives guarantee the base rate, it can be reasonably assumed that the worker would earn the minimum, particularly when the minimum wage law is considered. According to law (where it applies), a minimum wage must be paid regardless of output, and so the penalty aspect of the system would today nearly always be eliminated.

THE HALSEY PLAN

According to the Halsey plan, the bonus earned is split between the worker and management. In a sense, two rates exist: 1) an hourly rate and 2) a premium piece rate. The minimum hourly wage rate is guaranteed to both those who achieve the minimum hourly quota and those who cannot meet it. The premium piece rate is based on the percentage of time saved (only 30% to 50% of the money equivalent of the time saved). Management's share might be split again between the company and its supervisory personnel. The reason for this measure is obvious: To attain a high rate of production, it is essential that foremen keep supplying employees with work at the same rate they run out of it. Thus, the foremen must also be induced. An example is given in the accompanying table.

Worker	Performance		Hourly Rate	Premium, 50%	Weekly Income, 40 hr
	Quota, 60	Efficiency, percent			
A	120	200	$2.00	$40	+$80=$120
B	90	150	$2.00	$20	+$80=$100
C	60	100	$2.00	None	$80
D	30	50	$2.00	None	$80

The student may ask why the normal worker and the below-standard performer receive the same pay. Although they do, it should be understood that although the company guarantees base rates in general, it would not keep an employee on the payroll if he consistently fell 50% below the expected output.

THE ROWAN INCENTIVE PLAN

The Rowan incentive plan is very similar to the Halsey premium plan, the basic difference between the two being that instead of a flat rate for those attaining above-standard performance, varying premium rates are paid on the basis of efficiency. To clarify this, an employee saving, say, 33% of his time, performs 33% faster than expected. (Again the reader should note that here the time standard includes the allowance accorded for incentive purposes.) This employee is going to receive 33% premium, while another worker who saves 50% of the time allowed to perform the operation will receive 50% premium. Thus, the income increment of the Rowan incentive plan will be a little above that of the Halsey plan, at least as far as the early stages of performance above standard are concerned.

THE 100% PREMIUM PLAN

The 100% premium plan rewards workers not just partially for speed and surplus production but for all of it. That is, 100% of the dollar equivalent of the time saved goes to the employee. The calculation of the bonus payment is based on the employee's regular hourly rate of earnings. In a sense, employees are on day or hourly rate until they reach the standard hourly output requirement. Above that level, they are paid by a piece rate. However, where the 100% premium plan is in operation, the incentive increment is seldom higher than 15% to 20%, which, of course, is due to the smaller percentage of incentive allowance built into the standard output requirements.

THE GANTT TASK AND BONUS SYSTEM

The Gantt wage incentive plan has both time rates and piece rates and an additional 20% premium to be paid those who produce the quota or perform better than the quota. The employee who performs below the output requirement receives straight time wages. Those who produce at or above standard output requirements earn a piece rate wage that is paid on the basis of time saved, plus a 20% premium. Let us assume a job for which the hourly wage rate is $2.00 per 10 pieces. An example is given in the accompanying table.

Worker	Efficiency, percent	Hourly Wages, per week	Piece Rate (time saved), Plus 20% Premium	Total Weekly Earnings
A	200	$80	$80+$32	$192
B	150	$80	$40+$24	$144
C	100	$80	.....$16	$ 96
D	90	$80	.....	$ 80

The aim of the Gantt plan is to give the average and below-average performer an inducement to meet the standard requirement at least.

THE BEDAUX POINT RATING SYSTEM

In shops where job turnover is very frequent but where the jobs are more or less repetitive, it pays to introduce the Bedaux point rating system of wage incentive. Each operation has its own Bedaux point rating value based on careful time study. A Bedaux point, commonly called B, is the equivalent of 1 min of standard hourly output. Let us assume that a given job, say, one called "pipe fitting," is worth 40 B. For our present purposes it is unimportant how the time study man arrives at this figure. (Motion analysis might have discovered that the job consists of 30 motion elements and 10 rest stops each taking 1 min.) It is enough to know that the job is supposed to be performed in 40 min. Therefore, a Bedaux point represents both a unit of time and a unit of output. Wage payment is based on time as it relates to output. The example given in the accompanying table is somewhat unrealistic, because we

Worker	Efficiency, percent	Minutes	Hourly Rate	Earnings, per hr	Earnings, per week
A	200	20	$2.00	$4.00	$160.00
B	150	30	$2.00	$3.00	$120.00
C	100	40	$2.00	$2.00	$ 80.00
D	50	80	$2.00	$1.00	$ 40.00

have assumed the unlikely event that each employee works on the same job during the whole week. In a real situation this would probably never happen.

The reader may have noticed that this system requires a great deal of paper work and is therefore likely to prove expensive.

THE MEASURED DAY RATE

The measured day rate is hardly an incentive system, even though some enterprises consider it as such. Essentially, it is nothing more than a system whereby good performers receive periodic merit increases. To see when an employee deserves a merit increase, the foreman compares his output records over a period of time with the output indicated by the appropriate time standards. Although the "standard" cannot be enforced (which is a drawback), its advantage is that it is an *unofficially* used incentive system and the encroachment of the labor union is impossible. Furthermore, there is no reason to hide improvement in methods discovered by ingenious workers, because there is no quota or standard which is officially changed.

GENERAL COMMENTS ABOUT INCENTIVES

It should be emphasized that the name given to an incentive system means very little. Each system is of man's creation, the creation of a specific expert. As Fred W. Fogel, the editor of *Modern Machine Shop* stated once: "In the management field, for example, and perhaps more specifically in the area of incentive systems, we have found just about one expert for each system that is proposed and, unfortunately, many of these experts are highly opinionated. I have read considerably of various systems and proposals and I have listened at great length in both society meetings and in the private sessions sponsored by individual manufacturing organizations. I realize that there are, undoubtedly, a number of basic principles which could apply generally to industry but I also realize that variables enter into just about each and every system which also must be taken into consideration." This author tends to agree with the above statement, because the system to be applied depends largely on the circumstances under which the plant operates, the way the system is introduced and handled, and the method by which the plant arrives at the "quota" or "standard" which serves as a basis of the wage payment. Every system is good if it accomplishes what it purports to accomplish in every respect, namely, to benefit both management and labor.

appendix **D**

Modern Planning Tools—Detailed Description

The general concepts of machine loading and scheduling were explained in Chapter 9. This discussion is therefore concerned only with the use which can be made of modern visual aids in conjunction with scheduling. As a result of effective scheduling with such a device, the following results can be expected:

1. A clear picture is provided which shows available capacity to handle the backlog of old orders, incoming new orders in relationship to old ones, and immediate discovery of possible bottleneck stations in production.
2. Assurance of proper sequence of job handling to meet required deliveries.
3. Controls performance by measuring what should be accomplished and what is actually accomplished.

THE SCHED-U-GRAPH[1]

The Sched-U-Graph consists of a series of overlapping pockets. Figure D-1 shows a section of a Sched-U-Graph. There is one pocket for each machine and each pocket is 40 in. long and 5 in. high. At the left of each pocket is a 5-in. × 3-in. card which describes the machine. In this illustration, the card *1* is for machine number 700 Cylindrical Grinder. An opaque signal *2* which shows the number of hours per day that the machine works is inserted on the lower right corner of the 5-in. × 3-in. card. In this example, the number 15 indicates that 700 Cylindrical Grinder works 15 hours per day. Extending to the right of the index card *1* is a 35-in. long Machine Time Insert *3* which shows each day of the week divided into 10 periods.

When an Operation Record Card *4* is tucked under the transloid (clear plastic) tip of a pocket, behind the turned-up printed insert stub *3*, a solid (red) stripe on the bottom of the operation record card is visible showing that the machine is loaded and scheduled for the time covered by the stripe. Operation record cards are available for jobs requiring up to 6 periods and for

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[1] Courtesy of Remington Rand, Inc., 315 Fourth Avenue, New York 10, New York.

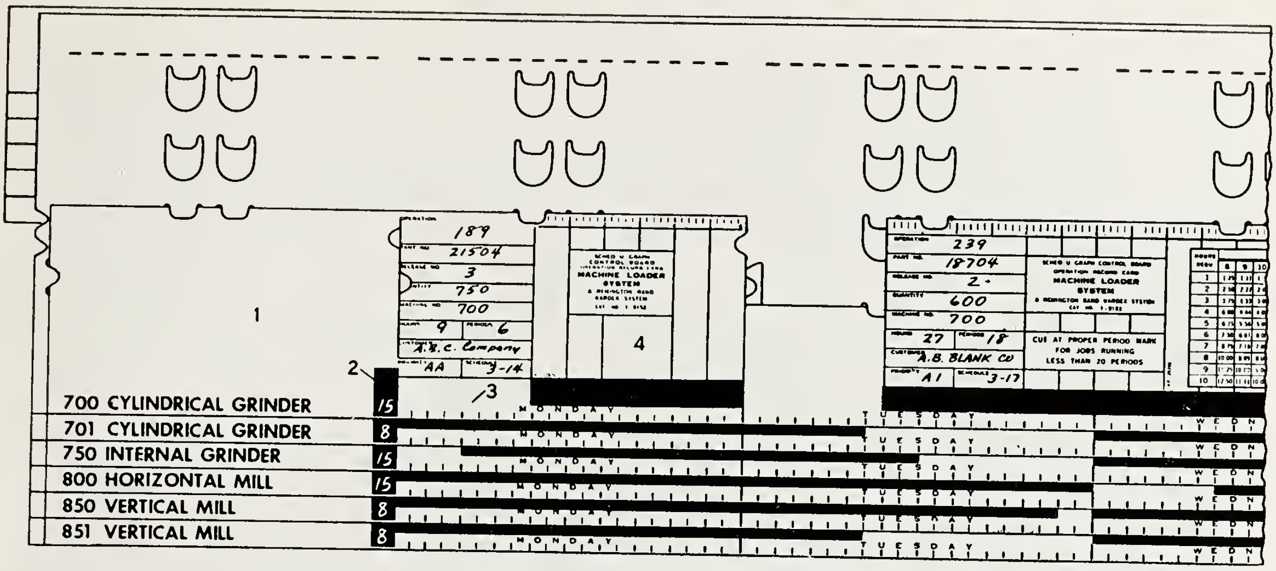


FIG. D-1. Sched-U-Graph. (Courtesy of Remington Rand.)

jobs up to 20 periods. The number of periods required to perform an operation is calculated by use of the following formula:

$$\frac{\text{Hours required}}{\text{Hours machine works per day}} = \text{days required} \times 10 \text{ periods}$$

The operation shown on the operation card *4* requires 9 hours which are readily converted to periods as follows:

$$\frac{9}{15} = 0.6 \times 10 = 6 \text{ periods}$$

A conversion chart printed on the large 20-period operation record card can also be used to convert hours to periods. After the number of periods required to perform the operation is determined, the operation card is cut off at the proper period graduation before it is inserted in the pocket.

The advantage of dividing the days into tenths of day periods is that there is no need to redesign the operation cards and other forms if the number of hours that a machine works per day is changed. Instead, when the hours that a machine works per day are increased, the operation card is cut to a shorter length and if the hours that the machine works per day are decreased, a longer card is used.

Since the red stripes will show loaded and scheduled time on the machine, the white spaces will show unscheduled time. Scheduling a job is, therefore, simply a matter of finding a white space large enough to hold the cut operation card, in keeping with promised completion dates.

When a clerk is scheduling a part which requires several machining operations, he must refer to the process sheet for the part so that the machines will be loaded in proper sequence. The clerk computes the periods for each operation and cuts the operation cards to the proper lengths. A separate folder is maintained for each machine center for each week, and each operation card is placed in the proper folder. Each folder has a visible tip and a Graph-A-Matic signal. When an operation card is placed in the folder, the signal is moved to the right a distance corresponding to the time required for the operation. Movement of the signal reduces the available time balance and the machine is thus rough loaded.

Each week the clerk removes the operation cards from their folders and after consulting the process sheet for the part, tucks the operation cards into the Sched-U-Graph pockets. The clerk must make certain that the part goes to the various machines in the proper sequence and must also allow transportation time between machines.

Rescheduling is very easy because the scheduled completion date is shown on each operation card and the time available on each machine is clearly visible. The clerk will simply shift the operation record cards in such a manner as to make certain that each job is completed by the scheduled date.

THE PRODUC-TROL[2]

How we progress toward the completion of a job can be seen on a progress chart. Chapter 9 explained that there are two lines on a progress chart, one representing the scheduled performance and a second one representing the progress toward it. The Produc-Trol board can be excellently enlisted to do the work of keeping track of orders in progress.

The Produc-Trol board consists of a large board with a large number of pegholes as shown in Fig. D-2. The board comes in different sizes on which a large number of jobs (and orders) can be kept track of simultaneously. An order may consist of 10 parts and each part is considered as a job, because it must be sent through the various operations required to make it assembly-ready. Only the finished part can be used. In other words, as far as the planner is concerned, each part is a job. In order to have every part ready prior to or at the time assembly should take place, it is essential to keep track not only of jobs but also of orders. Possible delays must be discovered in time so that remedial action can take place. Figure D-3, a portion of a Produc-Trol board, illustrates the Heading Strip (calibrated to match the pegholes in the board) which is interchangeable. As the months change, the heading strip may be easily changed. This heading strip can denote hours, days, weeks, months, or years. The Today Line is moved to the right each day (or whatever the calibration represents) and always appears over the current date.

The operation sequences and the scheduled date of completion for jobs are shown in the top row of Fig. D-3. In the second row of pegholes, which represent the progress toward scheduled performance, a retractable cord with a peg can keep track of progress.

[2] Courtesy of the Wassell Organization, Inc., Westport, Connecticut.

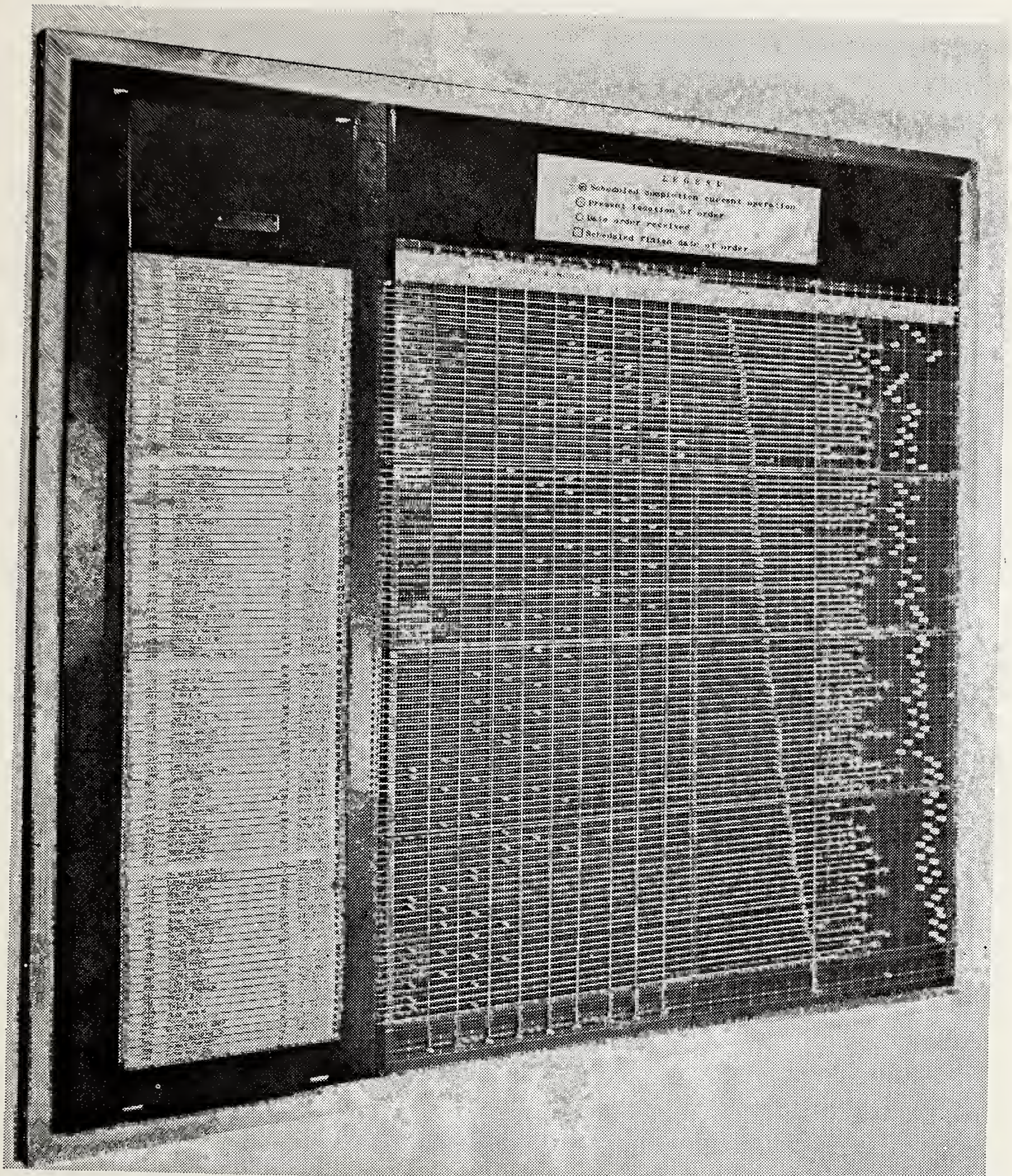

LEGEND
Scheduled completion current operation
Present location of order
Date order received
Scheduled finish date of order

Fig. D-2. Produc-Trol board. (Courtesy of Wassell Organization, Inc.)

Numbered pegs or pegs of contrasting color are placed in the top row under the dates when the various steps, operations, or phases on a job (a job may be a part, belonging to an order) are scheduled to be completed. The top order in this illustration is scheduled to be completed through the first operation or job on April 4. The Tape Peg is used to indicate either that work on the job has begun or that the operation or job was finished. This author prefers to place the retractable cord into the position after the shop reports to the production control department that the job has been completed. When the second operation is performed, the retractable Tape Peg is placed under operation No. 2 and so forth until the job as a whole is completed, that is, went through all the necessary operations.

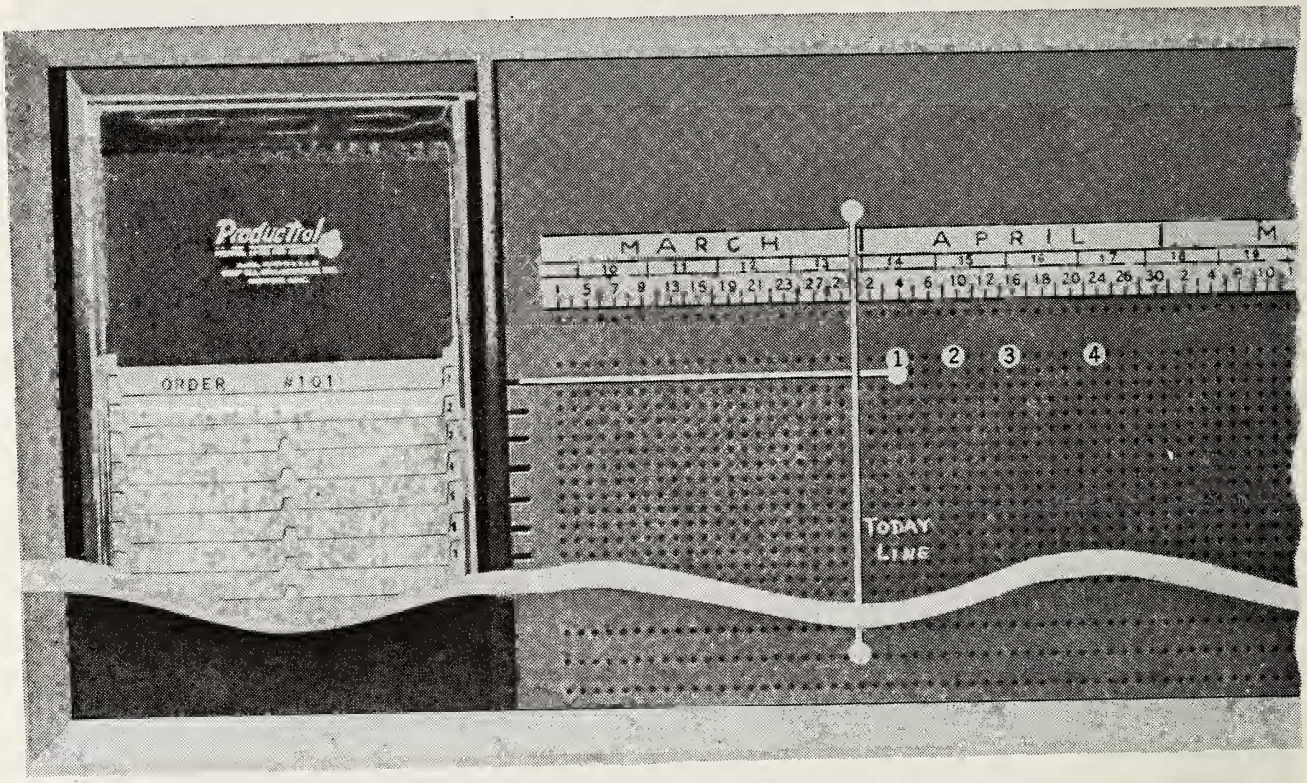


FIG. D-3. Section of a Produc-Trol board. (Courtesy of Wassell Organization, Inc.)

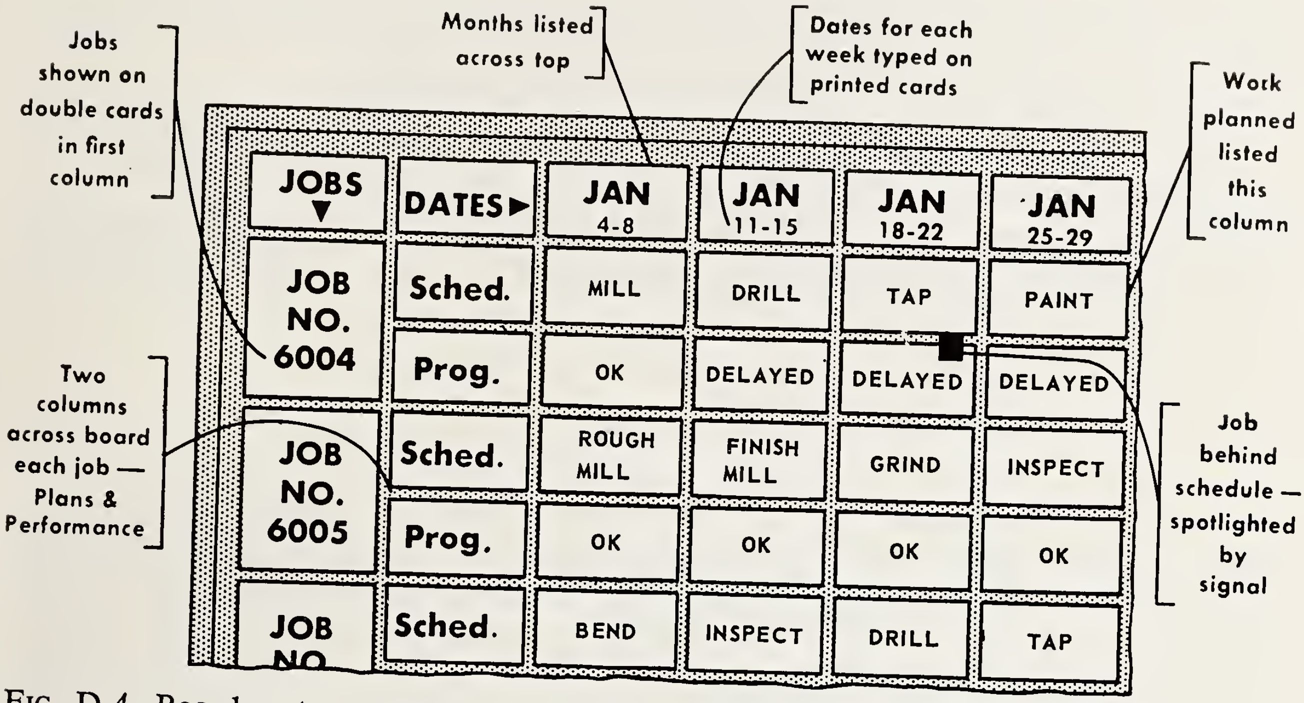
When an operation is performed, the Tape Peg is placed directly underneath the peg representing scheduled performance (that is, when the operation is scheduled to be completed). If one of the tape pegs falls behind the Today Line, the operation in question has been delayed and remedial action is necessary.

It should be noted, however, that it does not really matter how the production control people make use of the Produc-Trol board as long as it illustrates to them what they want to know and see. The method described has been used to progress control the scheduled operations with great success by this writer. Remember that any visual or other tool used in production is only as good as the use which is being made of it.

BOARDMASTER GRAPHIC VISUAL CONTROL[3]

Another system that lends itself to visual observation in production control work is the Boardmaster system. As shown in Figs. D-4 and D-5, this system can be used in either the scheduling or progress control areas.

[3] Courtesy of Graphic Systems, 55 West Forty-Second Street, New York 18, New York.

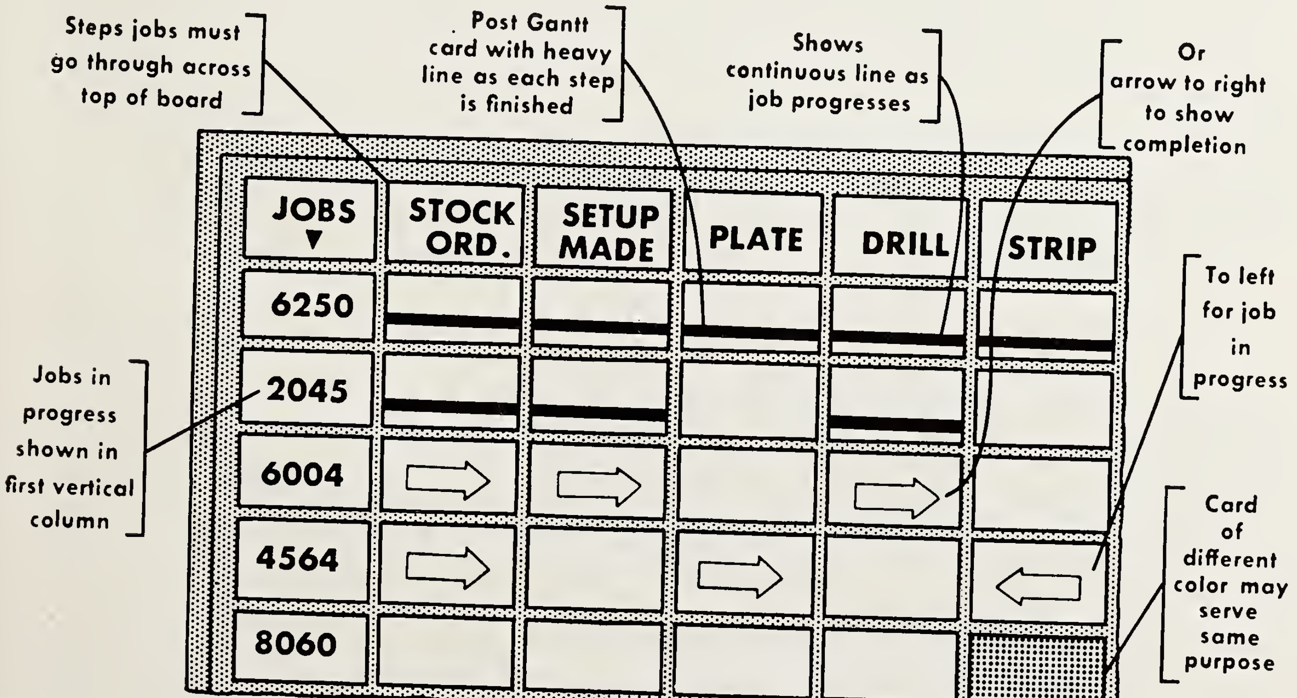

Jobs shown on double cards in first column
Months listed across top
Dates for each week typed on printed cards
Work planned listed this column
Two columns across board each job — Plans & Performance
Job behind schedule — spotlighted by signal

JOBS ▼	DATES ►	JAN 4-8	JAN 11-15	JAN 18-22	JAN 25-29
JOB NO. 6004	Sched.	MILL	DRILL	TAP	PAINT
	Prog.	OK	DELAYED	DELAYED	DELAYED
JOB NO. 6005	Sched.	ROUGH MILL	FINISH MILL	GRIND	INSPECT
	Prog.	OK	OK	OK	OK
JOB NO	Sched.	BEND	INSPECT	DRILL	TAP

FIG. D-4. Boardmaster system showing work accomplished against planned production on a week-to-week basis.

The Boardmaster units are 24 in. by 38½ in. in size. Each unit is designed with a series of basic spaces arranged in horizontal and vertical columns. Cards are available which cover one or more spaces.

Figure D-4 demonstrates how the Boardmaster system can be used to compare planned and actual performance of jobs on a week-to-week basis. Two horizontal columns are used for each job. The top horizontal column shows the planned or scheduled outline for carrying the job through to com-


Steps jobs must go through across top of board
Post Gantt card with heavy line as each step is finished
Shows continuous line as job progresses
Or arrow to right to show completion
To left for job in progress
Jobs in progress shown in first vertical column
Card of different color may serve same purpose

JOBS ▼	STOCK ORD.	SETUP MADE	PLATE	DRILL	STRIP
6250	━	━	━	━	━
2045	━	━		━	
6004	⇨	⇨		⇨	
4564	⇨		⇨		⇦
8060					▨

FIG. D-5. Boardmaster system showing step-by-step progress of a series of jobs.

pletion. The second horizontal column shows the actual progress that has been made each week and indicates whether or not the job is ahead or behind schedule. Signals may be attached to the cards if necessary.

The Boardmaster system can also be used to show step-by-step progress on a series of jobs as shown by Fig. D-5. Either printed cards or colored cards can be placed on the board to show job progress as shown by this illustration.

appendix E

Statistics of Sales Forecasting

Since statistics per se are not our field of primary interest, we restrict this section to their use in sales forecasting. Chapter 10 made frequent references to various techniques commonly used to predict future sales, but for various reasons it avoided the more technical discussion. If the basic concepts were understood, the chapter has accomplished its purpose. Nevertheless, a review of statistical inference techniques is highly desirable. It should be emphasized, however, that this discussion is intended to merely review the simplest statistical methods used in forecasting rather than attempting to impart any knowledge of statistics in general.

SALES FORECASTING TECHNIQUES

Depending on the nature of the product, companies can take recourse to various statistical tools in their sales forecasting work. Evidently, some of them may be more applicable in certain situations than in others. Several different techniques may be employed simultaneously, each to help check a prediction based on other forecasting techniques. Finally, the managerial decision may be a composite of several predictions based on accumulated statistical data. It should be remembered that statistics aid only in evaluation and prediction of future sales possibilities, but they do not make production decisions associated with the predicted sales. Nevertheless, when the data are properly arranged and evaluated, the statistical inferences which can be drawn will help the manager's predictive power.

TREND LINE

The trend sales can take may be ascertained by plotting past sales statistics. The vertical line should represent the sales (expressed either in dollar value or in output units) and the horizontal line, the time when the sale was made. By placing dots at the level where sales and years correspond, an ascending or descending series of dots will appear on the chart. Barring the unusual, by drawing a line which best fits those dots and subsequently extending it beyond them, it is possible to extrapolate future sales. This procedure is called trend fitting or regression analysis. The line can be drawn freehand, but precision requires a mathematical computation, usually employing the "least squares" technique.

Let us assume that in studying the sales statistics, the observation was made that the sales increase over each preceding year amounts to ¼ of a million units, based on a given base year (which we want later to designate as zero year). Under the assumption of 1 million pieces, the second year 1¼ million, the third year 1½ million pieces, etc. were sold. Although there is no guarantee that in the following year ¼ of a million more will be sold, if this has been going on for quite a number of years, one may suspect that the trend will continue—at least in the short run. This can be expressed mathematically as $Y_c = a + bX$ and be illustrated on a graph. The letter X in a sales forecast usually stands for the time factor, such as month, quarter, or year. The base year would be called 0 and subsequent years would be designated as 1, 2, 3, etc. The symbol a represents that section of the vertical plane where the curve begins and intercepts the Y line; at this point $X = 0$. The symbol b represents the slope of the curve and expresses the incline or decline it takes with the passage of each time unit (year, quarter, etc.). If b were to be zero, the curve would be perfectly horizontal. The symbol Y_c represents the trend values, whereas Y represents the vertical axes.

To make it easier to illustrate how the slope of the curve comes into being, each block in which a change in sales volume takes place—every year—has been divided into four quarters to notice the magnitude of the change. This can be seen in Fig. E-1. Figure E-1 depicts the tendency of sales to be greater every year by ¼ of a million pieces. By extending the sales trend (extrapolating the trend line) the forecaster gains a general idea as to what sales may amount to in the future.

It seems improbable however that the yearly sales increment is constant

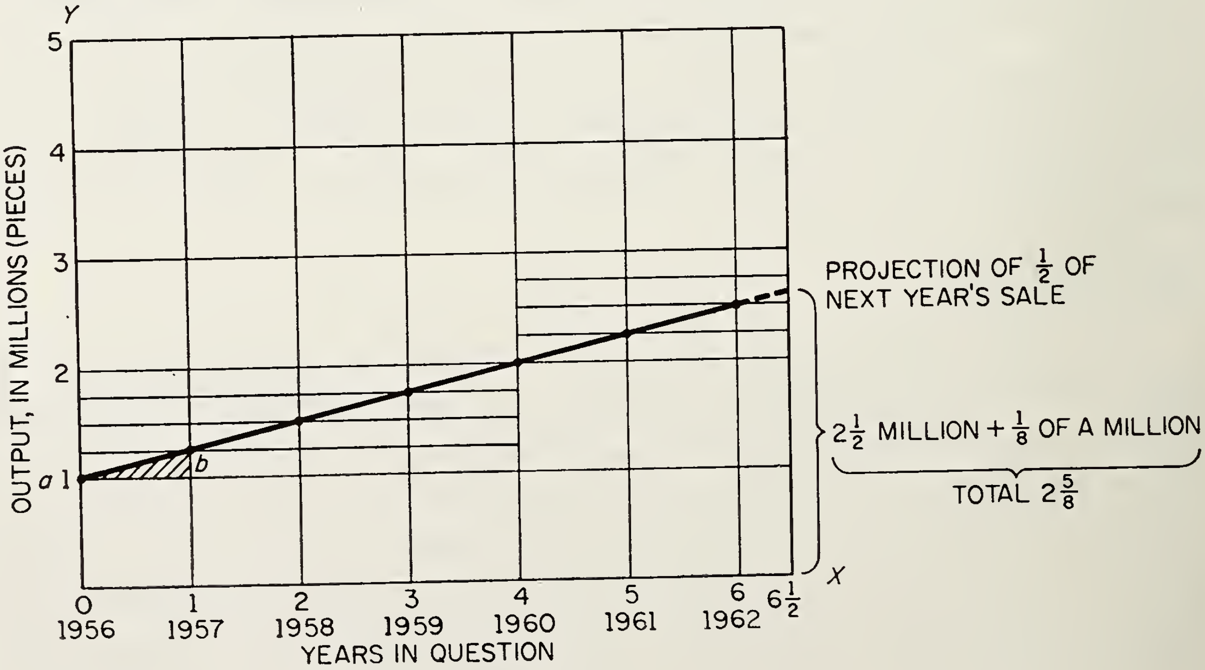


FIG. E-1

and that the yearly sales volume does not change from year to year. The tendency of sales may still be upward, but the sales volume may not fall on a straight line, such as Fig. E-1 has depicted. It may fluctuate rather violently as revealed by the following illustration. In that case, a line must be drawn which best fits all the points on the curve.

Figure E-2 was based on the semiaverage method of estimating trend lines. The data were divided into two parts, then averaged and plotted on the curve as indicated. The result is a more scientific trend line than attainable with the freehand method. Although this is far from being accurate, an extrapolation of the trend line may give a fairly good idea about future sales both for the long- as well as short-runs.

1933 to 1945 and 1947 to 1959

Year	Sales, in millions		Year
1933	5.14	6.18	1947
1934	4.65	8.80	1948
1935	5.18	9.33	1949
1936	5.45	5.47	1950
1937	5.21	9.00	1951
1938	5.72	8.95	1952
1939	4.95	8.80	1953
1940	4.99	9.88	1954
1941	5.95	9.96	1955
1942	6.94	8.75	1956
1943	7.38	8.89	1957
1944	7.53	9.08	1958
1945	8.00	9.15	1959
~~1946~~			

Extra year in the middle of time series is eliminated to give each part 13 years.

Totals

$1933/1945 = \frac{76.09}{13}$ $\qquad \frac{112.24}{13} = 1947/1957$

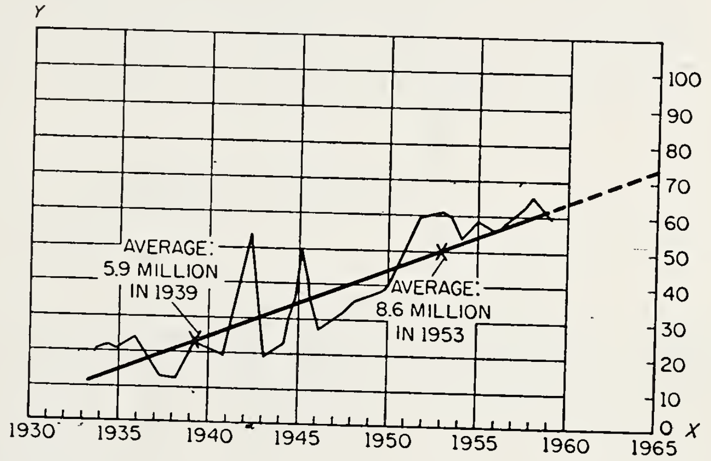


FIG. E-2

An improvement over semiaveraging of trend lines is the least squares method. In a sense, it does the same thing, but more precisely. Of course, precision is always questionable if based on the assumption that the sales of all successive years are linearly related to one another. The fact of the matter is that in most real situations sales do not increase proportionately, but at a decreasing rate. Here, the Gompertz's curve, $\log Y_c = \log a + (\log b)\ c^x$, would be considerably more useful. However, to avoid a complicated explanation, our discussion is restricted to the rather popular least squares method.

As said before, the semiaverage method and the least squares method represent averages. As a rule, the average of the trend values tend to equal the average of the actual values. However, in order to establish this, the slope of the trend line must be calculated. Through mathematical calculation the subjective judgment of the analyst is somewhat narrowed. It was said *somewhat* because the period how far we should go back to be accurate, the nature of the variance, and the type of least squares line to use remain always a matter of judgment. In other words, let us not believe that the statistical methods are by any means foolproof.

Depending on the accuracy we seek, it is possible to improvise in order to take advantage of short cuts. Accordingly, we have a long least squares method and its short-cut counterpart; each will yield pretty much the same result. When computers do the calculation, there is no need to take short cuts. If we are pressed for time, the short cut will be more advisable.

To use the following formula to calculate the straight line $Y_c = a + bX$, we must pick an odd number of years (otherwise we would complicate things):

$$a = \frac{\Sigma Y}{N} \qquad \text{and} \qquad b = \frac{\Sigma XY}{\Sigma X^2}$$

To use this abbreviated method is advantageous in so far that it makes it unnecessary to solve two simultaneous equations merely to obtain the value of *a* and *b*. Figure E-3 will illustrate the short-cut method.

Middle of Time Series

Year	Sales or Output, in millions			XY	Ordinate of Trend
	Y	X	X^2	a × b	Y_c
	a	b	c	d	e
1956	132	−3	9	−396	133
1957	134	−2	4	−268	122
1958	103	−1	1	−103	111
1959	83	0	0		100
1960	99	1	1	99	89
1961	87	2	4	174	78
1962	60	3	9	180	67
Total	700	$\Sigma X = 0$	28	−314	

$$a = \frac{700}{7} = 100 \qquad b = \frac{-314}{28} = -11 \qquad Y_c = 100 - 11X$$

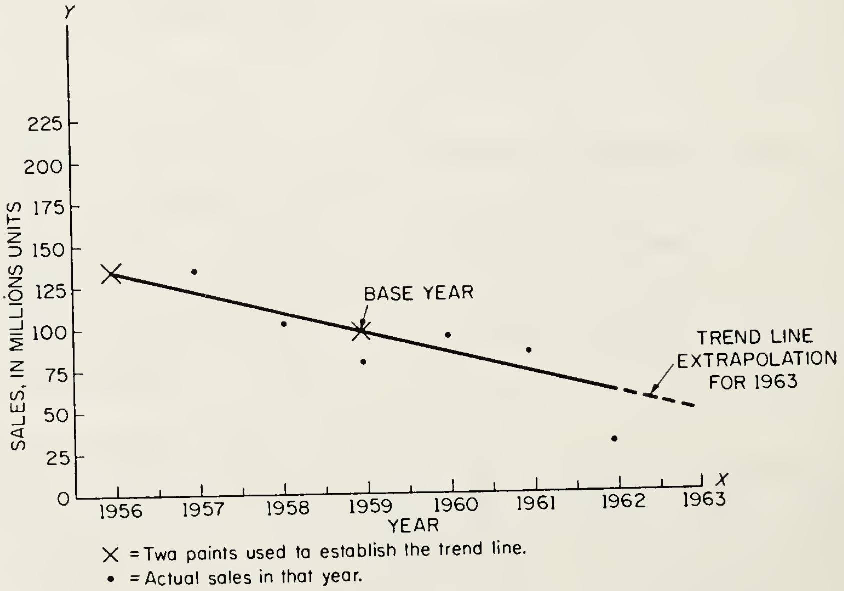


FIG. E-3

After plotting the curve it becomes immediately apparent that we are dealing with a product for which the demand decreases as the years go by. Because this is a regression line, the equation for Y_c becomes $Y_c = a - bX$, based on the $Y_c = a + bX$. To reduce computation, we arrange the data so that $\Sigma X = 0$. This was attained by dividing the data into two parts and using the datum in the middle of the time series as the dividing line. Going out from this middle line, up or down, we assigned to the years negative and positive values, respectively. Thus, we ended up with $\Sigma X = 0$. The slope of the curve then in the base year of 1959 is assumed to be zero. As we look back into the past it rises; as we go to the right, it falls in accordance with the value of b (the slope of the curve, which in this case originates in mid-range). Thus, the trend line extrapolation indicates the sales possibility as being approximately 50 million units in 1963.

Year	Y	X	X^2	XY
1956	132	0	0	0
1957	134	1	1	134
1958	103	2	4	206
1959	83	3	9	249
1960	99	4	16	396
1961	87	5	25	435
1962	60	6	36	360
Total	$\Sigma Y = 700$	$\Sigma X = 21$	$\Sigma X^2 = 91$	$1780 = \Sigma XY$

FIG. E-4

With the longer method of least-squares (see Fig. E-4), the data would remain pretty much the same, except the X column is not equal to zero. Accordingly, the formula should read:

$$\Sigma Y = Na + b\ \Sigma X$$

$$\Sigma XY = a\ \Sigma X + b\ \Sigma X^2 \qquad \text{and} \qquad Y_c = a + bX$$

and when the appropriate figures are substituted:

$$\begin{aligned} 700 &= 7a + 21b & \qquad b &= -11\tfrac{3}{7} \\ 1780 &= 21a + 91b & \qquad a &= 134\tfrac{2}{7} \end{aligned}$$

thus, $Y_c = 134\tfrac{2}{7} - 11\tfrac{3}{7}$.

CONVERTING YEARLY ESTIMATES TO MONTHLY PRODUCTION

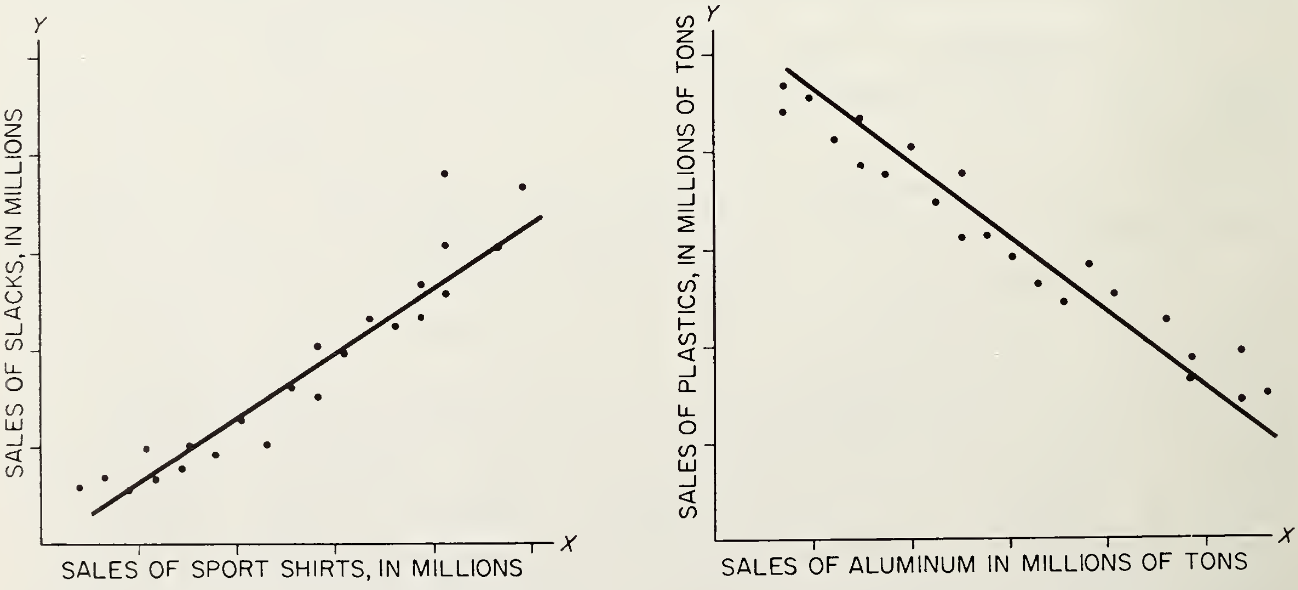
So far a forecast was made on the basis of past experiences about future yearly sales. From the production point of view, however, we want to know how much is required every month. As it is, in certain months of the year there is a seasonal demand which requires more production. The bathing suit manufacturer is bound to have a much greater demand for bathing suits during the summer than during the winter months; more demand during the late spring than during the early winter. This *seasonality of sales* must also be established in the accumulated data. The tabulation of monthly sales of the past few years may reveal that 75% of the bathing suits were sold from March to August and that 25% of all sales took place from September till February. Equipped with this knowledge, production of, say, 100,000 suits can be planned so that 75% (75,000) will be produced during the six off-season months at a monthly rate of 12,500 ($\tfrac{1}{6} \times 75{,}000$) to meet peak demand, while 25% (25,000) will be produced during the remaining six months at a monthly rate of 4166 (1/6 × 25,000). What we really do is determine the percentage of each month's sales based on the total. Then we apply this percentage to the total yearly sales to establish the monthly output requirements based on the forecasted total.

The determination of seasonal changes can be complicated depending on the accuracy we seek. Generally speaking, however, the difference between the various methods used to accomplish the measurement lies chiefly in a difference in the ways of securing the values to be averaged. In most, though not every situation, the average monthly sales over a period of years as a percentage of the total yearly sales will give a pretty good index of seasonal variation.

Because Chapter 13 deals at length with this subject in light of production scheduling of standard items (continuous production), further discussion at this place is not warranted.

CORRELATION

If the sale of one item is related to the usage of another, either in a positive or negative way, we speak of having a correlation between these two items. Of course, sales of a company can be correlated with some economic factor, such as the disposable income. Say, a study of accumulated company sales figures and a comparison of the data thus ascertained with disposable income may reveal that when disposable income increased, the sale of the item in question increased also. At first, such a relationship is suspected, but to make sure of the existence of a correlation, it is essential to subject the data to careful scrutiny. This study can take the visual form with the help of a scatter diagram (see Fig. E-5) and the drawing of a chart similar to the one already discussed in conjunction with trend line extrapolation. Let us see, now, how the existence of a correlation between two factors can be tested.



(a) EXAMPLE OF POSITIVE CORRELATION

(b) EXAMPLE OF NEGATIVE CORRELATION

Fig. E-5

The more the dots on the diagram scatter, the less the relationship between the data. By the same token, if they are squeezed together, there is a close relationship. Mathematically speaking:

$$\underbrace{1.00 \text{ to } 0.90}_{\text{High}} \longleftrightarrow \underbrace{0.50 \longleftrightarrow 0.25}_{\text{Some}} \text{ to } 0$$

High — Good — Some — Little or no correlation

In other words, how strong is the correlation is another problem and can be measured mathematically. A precise measurement makes the difference between the freehand and the computational method when it comes to determining the correlation between two or more factors. The so-called coefficient of correlation measures then the degree of relatedness between two or more series of data.

The actual calculation of the coefficient of correlation is not only a formalization of the aforesaid method but also a measure of considerable accuracy. It is a ratio and thus it is not affected by the units in which the data are expressed. It has the further advantage of varying between fixed limits 0 and 1.

Before explaining the mathematical approach to establishing correlation, it may be worthwhile to mention that the scatter diagram's value can be enhanced if the two variables are depicted with colored pencil—two different colored points is an effective method of depicting as to which dot belongs to which of the individual series.

To simplify the explanation here, just as in the trend line determination, we will assume that arithmetic straight lines describe the functional relationship between variables. In other words, the assumption will be made that a given increase in X is accompanied by a change (though not necessarily a quantitatively corresponding change) in Y of constant amount. But, it should be noted that it is often necessary to employ parabolas in describing a given functional relationship as well as in computing its trend line. The latter can be illustrated as in Fig. E-6.

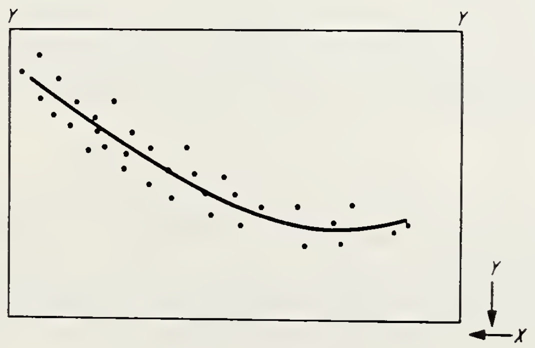


FIG. E-6

A general expression of the second-degree of parabola is $Y_c = a + bX + cX^2$, but, of course, what mathematical measurement should be used depends always on the specific nature of the curvilinear relation between the factors under observation. The above are described as "curvilinear correlation" as opposed to the herein discussed "simple correlation" which assumes straight-line functions of two variables.

To illustrate (see Fig. E-7) the measurement of simple linear (as opposed to curvilinear) correlation between two series (as opposed to more than two series) of collected data, let us assume that as the disposable income (in billions) increases, the sale of the item also increases (in millions of dollars).

Year	X Disposable Income, in billions	Y Sales of Item, in millions	X^2	Y^2	XY
1958	7	15	49	225	105
1959	5	7	25	49	35
1960	6	10	36	100	60
1961	10	20	100	400	200
1962	4	8	16	64	32
Total	32	60	226	838	432

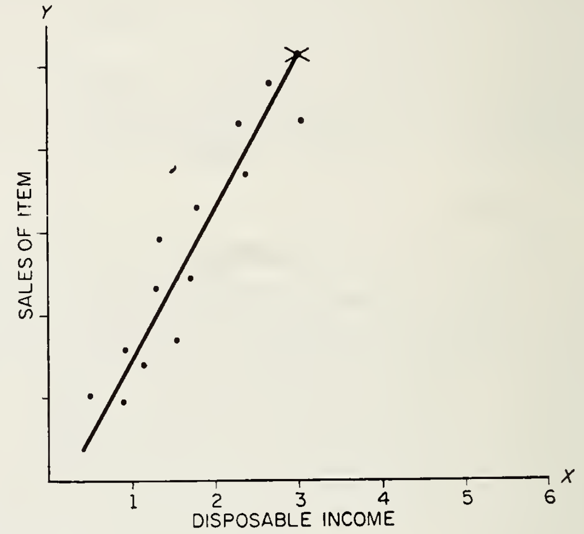


FIG. E-7

Then let X represent the disposable income and Y the item in question. The equation for the trend line, after determining a and b, is

$$a = \frac{\Sigma X^2 \Sigma Y - \Sigma X \cdot \Sigma XY}{N \ \Sigma X^2 - (\Sigma X)^2} = \frac{(226)(60) - (32)(432)}{5 \times 226 - (32)^2} = -0.262$$

$$b = \frac{N \cdot \Sigma XY - \Sigma X \cdot \Sigma Y}{N \cdot \Sigma X^2 - (\Sigma X)^2} = \frac{5 \times 432 - (32)(60)}{5 \times 226 - (32)^2} = 1.7$$

$$Y_c = a + bX \qquad \text{or} \qquad Y_c = -0.262 + 1.7X$$

Therefore, to determine the values of Y from X, we merely substitute the appropriate numerical scales in the equation $Y_c = -0.262 + 1.7(?)$, where the question mark stands for (X) of any numerical value. Because a gives a value of Y_c when $X = 0$ and b, the typical change in Y associated with specific changes in X, all values associated with one another can be determined and plotted on a curve. The straight line curve shows the trend line, in this case the line which shows the relationship between the X and Y values. Unless there is a perfect correlation of 1.00, few of the values will fall exactly on the line thus shown. The closer the correlation, however, the closer to this line will fall the actual values taken from sales records and disposable income records of the past. Judging the correlation between the various dots, based on the slope of the curve, we suspect that there is a close correlation between the disposable income and the sales figures. The question is, however, how close is the closeness? This can be established through statistical means (manipulations) by determining the possible errors we made in the estimates. It stands to reason that a comparison of the standard error of estimate of $Y(S_y)$ and the standard deviation of Y (σ_y) yields a clue as to whether there is correlation between X and Y. Of course, by glancing at the chart, it is readily apparent that there is one.

Thus, a comparison of above will provide the basis for the computation as to the degree of correlation. It should be noted however that the custom is to square them (multiply them by themselves) rather than using the data directly (S_y^2 and σ_y^2) and subsequently obtain the ratio of the squared standard error of estimate to the squared standard deviation. When the standard error of estimate is zero, there is perfect correlation. The latter is a problem, however, in the theoretical sense because logically zero means that there is no correlation. To remedy such misleading conclusions, the formula used to determine the coefficient of correlation (for which the symbol r is used) is modified as follows:

$$r = \sqrt{1 - \frac{S_y^2}{\sigma_y^2}}$$

It seems then that in order to establish the measure of the existing correlation between the disposable income and the company's sales, we would have to go about it in a roundabout way, namely, obtain S_y and σ_y and then secure the value of r. In this simple explanation we do not want to do this. Therefore, we are going to explain the determination of the degree of correlation in a short-cut, and simplified, way.

The aforementioned method of computing r is based on the least square method because the trend line constitutes the basis of the S_y *and* σ_y calculations. If we do not want to visualize the trend line and compute the standard error of estimate, it is more convenient to use the following formula:

$$r = \frac{N \cdot \Sigma XY - \Sigma X \cdot \Sigma Y}{\sqrt{[N \cdot \Sigma X^2 - (\Sigma X)^2]\ [N \cdot \Sigma Y^2 - (\Sigma Y)^2]}}$$

In order to get r let us substitute the data from Fig. E-7, as follows:

$$r = \frac{(5)(432) - (32)(60)}{\sqrt{[(5)(226) - (32)^2]\ [(5)(838) - (60)^2]}}$$

$$= \frac{240}{\sqrt{(106)(590)}} = \frac{240}{\sqrt{62{,}540}}$$

$$= \frac{240}{250} = 0.96$$

Since the answer is close to a perfect correlation, the assumption can be made by the company making the sales forecast that any expected rise in disposable income will indeed precipitate a rise in sales which corresponds to the change in the disposable income.

As Chapter 10 made it perfectly clear, statistics is a tool which helps the forecaster's predictive power. Therefore, either trend analysis or statistical correlation analysis may lead to erronous results. To avoid errors in forecasting, the statistical tool should be used more or less as a check of the logical and theoretical analysis on trends which take place (or seem to take place) in the economy and economic life of the firm or on the relatedness between variables influencing a company's sales and, ultimately, the company's production decisions.

This brief description of the statistical tool in conjunction with sales forecasting is obviously superficial. The reader must therefore learn the sophisticated techniques in the appropriate statistics course or read any one of the better books on statistics.

appendix F

Inventory Control: Stock Items

If inventory control seems to have been neglected, it was done both to enable better coverage of the production scheduling problem and because of its subordinate role. It would seem obvious, however, that in any efficient business, inventory levels are established with as much care as production levels, because overall profitability is derived from minimizing every cost element regardless of its source. A careless choice of the inventory level can easily precipitate production slowdowns caused by lack of badly needed materials. As a rule, inventory levels cannot be set too low, but in view of the costly nature of high inventories, they cannot be set too high either. Accordingly, the problem can be solved by storage of just enough materials, not too much or too little. Admittedly, this is a vague statement and to assume meaning, it must be translated into quantitative terms.

Whereas the best assurance for an uninterrupted production would be the highest possible inventory level of stock items, because of the reciprocal relationship between the costs of production and the costs of carrying inventories, a simultaneous consideration of both becomes necessary. Because of the tendency of the one cost to go up when the other cost declines, the setting of the inventory level becomes always a compromise and it is best attainable through careful mathematical computations.

In the past inadequate attention was paid to inventory costs, not because their importance went unrecognized, but because the calculation of inventory levels, particularly where several thousand stock items were involved, represented a formidable task. Often it was cheaper to set high levels of inventory than to go through careful mathematical computations. With the advent of the computer, however, things have changed. The necessary calculations can now be made efficiently. Once the computer has been programmed, it is but routine to figure out the least-cost inventory levels. This is where mathematical formulas become of practical value. Mathematical models can be designed either to minimize size and stock-out probability of inventories or to set reorder points, safety and economic quantities. As a result of tighter controls over inventoried items and meticulous record keeping, the costs of maintaining adequate levels of inventories has been reduced without adverse effects on the continuity of operations.

It should be noted, however, that the time-consuming nature of developing and computing inventory levels with paper and pencil techniques makes most methods theoretical rather than practical. Another serious limitation, which computer programmers attempt nowadays to remedy, is that most mathematical methods are applicable if and when the lead times, the rate-of-use quantities, the material prices, etc. are reasonably stable and no piecemeal shipment takes place. That we are speaking here of serious limitations goes without saying. If everything clicks, however, one can say in favor of mathematical models that they will establish uniform inventory levels because the computer applies the same yardstick to every calculation. In other words, once the computer is programmed, all calculations will follow the same rule, whereas in the past different men set the inventory levels and therefore different judgments were used depending on who set the inventory level. If the one individual placed greater emphasis on safety or on the reliability of lead times, the maximum or the minimum level turned out to be different. The computer does not think, it merely follows mathematical instructions.

Where the rate of use of an item is not constant and inventory levels are set so that the stock-out probability is minimized, even the computer programs are highly questionable. The reason is that a great deal of conjecture is involved when the costs of stock-out is estimated. Here, through study of past trends, the normal usage is established and the function of the formula is to establish the practical minimum, according to which, as long as the stock room does not run out of materials most of the time, everything is all right. An occasional inventory shortage may still be cheaper in the long run than to carry high levels of inventory all the time. It is attempted therefore to minimize both the stock-out probability and the inventory level in view of minimizing the costs of carrying inventories.

For the sake of brevity, let us begin the explanation of how some of the calculations are made to keep inventory cost low yet maintain orderly flow of production by recalling the previous appendix dealing with linear and curvilinear relationships. The cost curve is usually nonlinear in nature. Therefore it can be constructed in the same manner as any other curvilinear relationship mentioned in Appendix E. Since the computation of economic lot quantities can be facilitated by the use of a cost curve, let us start with the determination of economic production (purchase) lots.

ECONOMIC LOTS

In order to minimize the cost of stock items, economic lots are ordered. This means that a particular lot size will minimize both the inventory cost and the production cost (or procurement cost). Through empirical data, a cost curve can be constructed. The cost of purchasing (making) and storage (including all the costs associated with storage) of different sizes (order quantities) must be plotted on the Y axis relative to the lot size depicted on the X axis. When the various dots placed on the graph are connected, a curve can be drawn freehand which would look like Fig. F-1. The economic lot quantity is the one which is at the lowest level of the curve. At this point the combined cost of procurement and storage is the lowest. Of course, in order to draw up such a curve, it is essential to have cost data available from past purchases (production) and storage. Basing our discussion on Appendix E, we are bound to be somewhat familiar with the construction of the curve. We can read off the curve the most economical lot quantity.

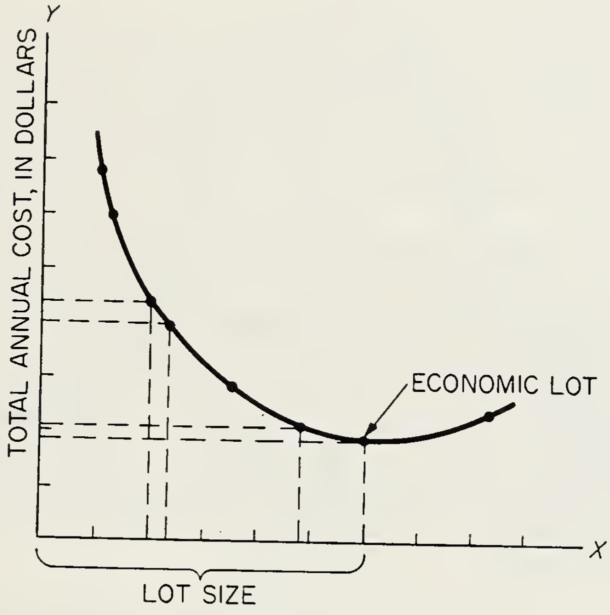


FIG. F-1

The general slope of the curve can also be calculated and expressed in equations. Such a curvilinear relationship between costs and lot sizes could be expressed mathematically as: $Y_c = a + bX + cX^2$. This is a formula which has already been mentioned, though not discussed, in Appendix E. The exact slope of the curve at a particular point can be ascertained through the solution of three equations:

$$\Sigma Y = Na + b\Sigma X + c\Sigma X^2$$

$$\Sigma XY = a\Sigma X + b\Sigma X^2 + c\Sigma X^3$$

$$\Sigma X^2 Y = a\Sigma X^2 + b\Sigma X^3 + c\Sigma X^4$$

where a is the value of Y_c at the origin, that is, for the annual cost of carrying the corresponding lot size; b is the slope $X = 0$; and c is the value which indicates the extent of deviation from linearity. The lot size is the independent variable and the total annual cost is the dependent variable. The advantage of calculating the slope of the curve with the aforementioned three equations lies in the fact that it can take minor fluctuations in price and other changing cost elements into consideration.

The same can be ascertained by the application of Mayer's[1] formula:

$$Y=C\cdot P+\frac{C}{X}(O+T)+\frac{X}{2}(I+S+D)$$

where $I =$ the interest paid on invested working capital,
$S =$ the storage cost,
$D =$ deterioration of inventory (obsolescence),
$O =$ the ordering cost (setup cost),
$T =$ trucking cost.

By substitution of different lot size values for X, the economic lot size can be established in the same manner as with the use of the graph in Fig. F-1. Once the graph is established, any additional calculation becomes unnecessary because the economic lot can be read off the chart. Of course, by reading the curve, it is easy to make errors because it is difficult to find the exact location of the low point. It should be noted, however, that the error is so minimal that an approximation is quite adequate.

There are as many economic lot size formulas as there are different production situations. Most economic lot formulas use symbols instead of the words appearing below in Moore's formula[2] to depict cost and quantitative relationships. Moore illustrates, however, that basically all formulas will show something like the following:

$$\text{Economic lot}=\sqrt{\frac{2\times\text{number of pieces per year}\times\text{setup cost per one setup}}{\text{cost per piece}\times\text{rate of inventory carrying charge}}}$$

A considerably more complicated and detailed example of an economic lot calculation has been shown in Chapter 12, page 535.

MINIMUM INVENTORY

The minimum inventory depends largely on the reorder point and on the safety quantity the company decides to keep on hand to compensate for the possibility of errors in forecasted rate of use or shifts in the lead times. The safety quantity cushions the effects of delays no matter what the cause. Of course, to know how much error in forecasting or delay in shipments may occur, past data must be analyzed. If a frequency distribution of errors in a forecast, assuming a normal distribution, are plotted on a bell-shaped curve

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[1] Mayer, R. R., *Production Management* (New York: McGraw-Hill Book Company, Inc., 1962), p. 338.

[2] F. G. Moore, *Production Control* (New York: McGraw-Hill Book Company, Inc., 1959), p. 369.

(see statistical quality control, Appendix B), it is possible to see how many of the errors fell, say, 5%, out of the normal distribution of 95%.

It is sufficient to remark at this point that the *Gussian curve* which represents the normal distribution has well-defined mathematical properties and that statistical sales data affected by a number of causes tend to follow the general bell-shaped form shown in Fig. F-2. Thus, by checking the data, in the same way as defective pieces are collected and classified according to the frequency with which they are undersized or oversized, we find how much the sales forecast deviated from the actual sales. Moving from left to right along the error axis will reveal the probability of the error in forecast is less than, or equal to, the corresponding value of the error. If the right corner of the accumulative area (shaded) under the curve represents 5% of the total, then only 5% of the time, that is 5 times out of 100, is the error in forecast greater than 4½ units. (A unit may be any figure: one hundred, one thousand, or one million.) Consequently, the assumption can be made that if 4½ units are always added to the inventory stock requirements, the stock-out condition should occur only for errors larger than 4½ units, or only 5% of the time. It should be noted that items used pretty evenly need small safety stock, but those items with wide fluctuation in sales will have large safety stock to contend with.

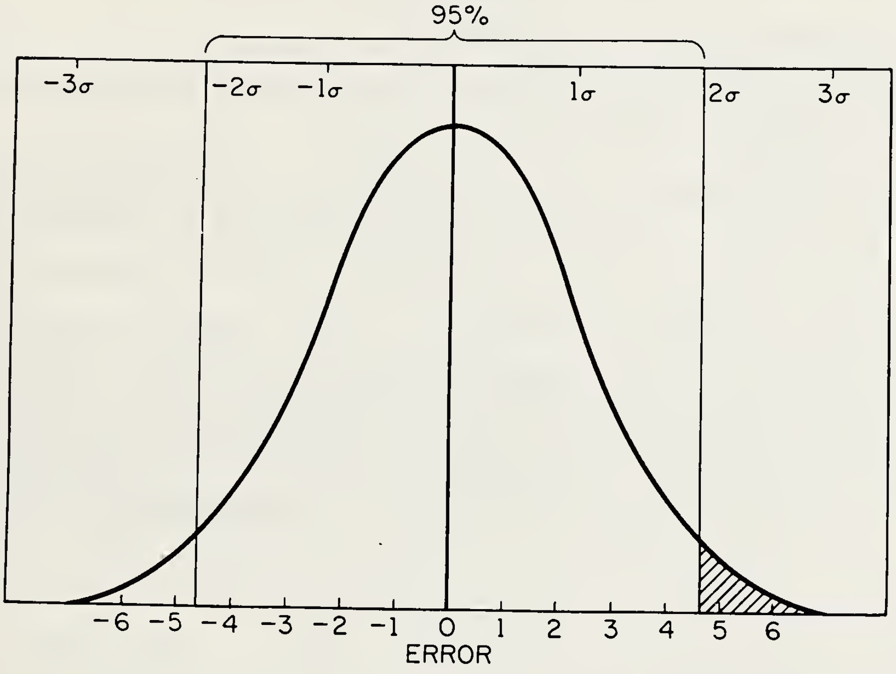

FIG. F-2

The same kind of analysis can be made for probable delays in lead time. However, if the forecasting error were expressed in units, the delay of two days, for instance, must also be translated into equivalent units based on the normal rate of use. Then the safety for sales forecasting errors plus safety quantity for probable delays will give the company's safety quantity.

For calculating the same proper error value for a stated probability, the transformation equation $t=(x-m)/\sigma$ may be employed, where t represents the value which corresponds with the required probability level and is derived from the tabulated values available for the normal distribution, x represents the desired error value, $\sigma=$ the standard deviation of error, and $m=$ the mean of the errors. Finally, $x=\sigma t$.

Equipped with such information, the company knows how much it should keep in stock as a safety against errors in forecast or in lead times.

THE MINIMUM-MAXIMUM SYSTEM

The discussion so far has shown how economic lots and safety quantities are calculated. Accordingly,

Economic lot quantity + safety quantity = maximum inventory

Because from the time an order is placed until it is received some time will elapse, the company must also decide on the reorder point. If we assume that the economic lot quantity is 1000 units, the rate of use is 10 pieces a day and the lead time (the time it takes to obtain a shipment counting from the day the order is placed) is also 10 days, then the reorder point, under assumption of 100 units of safety quantity, is 200 units (100 units safety + 10 days × 10 units per month = 200 units). Accordingly, the 1000 units will be delivered at the time 100 units are still on the shelf. Thus, the maximum inventory, under the proviso that no deviation from the sales forecast or delay in shipment arises, is at all times 1000 + 100 = 1100 units. The reorder point is reached when 200 units (pieces) are still on the shelf. The system can be illustrated in a schematic fashion as shown in Fig. F-3.

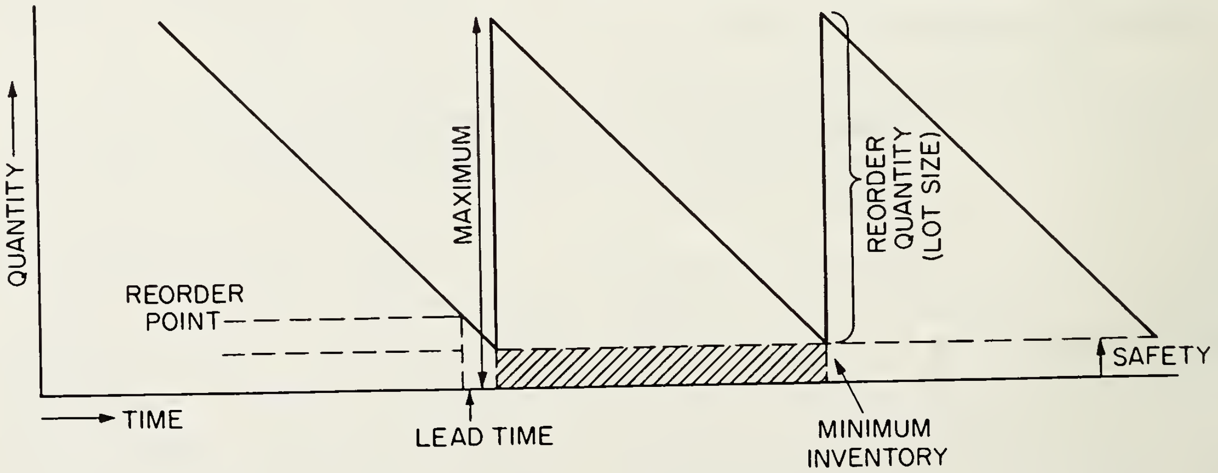

Fig. F-3

It was mentioned that the minimum-maximum system of inventory control is useful if most of the elements (material price, lead-times, rate of use quantities, etc.) remain reasonably constant. In many respects, this may not be such a significant handicap. For instance, if there is an increase in the rate of use due to errors in the forecast, this may work in both ways. Thus, overage and out-of-stock conditions may equate one another, aside from the already explained safety quantity which is supposed to cushion the impact of demand changes which go beyond the expected sales volume. A further element is that the reorder point may soften the impact in view of the fact that a more rapid use of the inventories will precipitate an earlier placing of the order for an economic lot than would otherwise be the case (for example, had it been placed at the precise time as originally foreseen).

IRREGULAR USE OF INVENTORIES

Although a certain pattern is necessary to set up inventory models, the probability approach may help where the sales of the item for which materials are being stored are uneven. In that case the sales would have several peaks occurring at irregular intervals. As long as each spurt in sales (values) is associated with measurable probability values, it is possible to set minimum levels which will assure the availability of materials without paying an exhorbitant price for safety. The above problem will not be dealt with here, however, because of the rather lengthy explanation required, in addition to making reference to the complex nature of the probability theory. It should be noted, however, that systems have already been developed which seem to work in such selected situations.

appendix G

Operations Research

Although Chapter 15 mentioned something about matrix algebra, beyond making the statement, no further details were given. The main reason for this was that those unfamiliar with the special symbolization system and the computational methods would have experienced difficulty in following a matrix presentation. Yet, the same individual could easily follow the more customary algebraic expressions. Therefore, with the exception of the index method (upon which the first example was based), none of the examples used matrices.

The preference of operations researchers for the use of matrix algebra, in lieu of the orthodox algebraic expressions, lies primarily in the fact that matrices permit presentation of complex problems in a highly abbreviated form. Secondly, and for practical reasons this may be even more important, matrices are particularly well suited for computer application and linear programming techniques. It follows then that the new system differs only in form, not in concept. The same type of equations and systems of equations (with unknown elements) are solved in matrix algebra as has been illustrated in Chapter 15, but, of course, in different form and manner.

THE SYMBOLIZATION

In addition to symbols discussed previously, matrix algebra has some of its own. The problems however will be presented in matrix notation. A matrix is a method of arranging numbers (or symbols) in an array, reading from left to right as *rows* (like a row of buildings) and up and down as *columns* (like house blocks). A row or column may be referred to as vector. If the numbers in the main diagonal are identical (see Fig. G-1), but unequal to zero, we speak of a scalar matrix. This concept will become more meaningful when used in context. Thus, we must learn more about it. An extremely useful matrix in solving problems of linear equations contains the number 1 in the main diagonal. The latter, illustrated among the matrices in Fig. G-1, is the *identity matrix*. Note the use of lines, brackets, parantheses and double lines. It does not matter what is being used to indicate that the set of numbers are a part of a matrix.

$$\begin{array}{cccc}
\begin{vmatrix} 3 & 3 & 5 & 6 \\ 2 & 5 & 3 & 6 \\ 2 & 9 & 4 & 3 \\ 3 & 6 & 7 & 2 \end{vmatrix} &
\begin{bmatrix} 6 & 0 & 0 \\ 0 & 6 & 0 \\ 0 & 0 & 6 \end{bmatrix} &
\begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix} &
\overbrace{\begin{Vmatrix} 9 & 3 & 5 & 7 & 8 & 9 & 9 \\ 1 & 0 & 9 & 6 & 5 & 4 & 3 \\ 7 & 9 & 7 & 2 & 1 & 3 & 5 \end{Vmatrix}}^{\text{7 columns}} \left.\vphantom{\begin{matrix}1\\1\\1\end{matrix}}\right\} \text{3 rows} \\
\text{Matrix} & \text{Scalar Matrix} & \text{Identity Matrix} & \text{Matrix of the order of } 3 \times 7
\end{array}$$

FIG. G-1

Although it is customary to use different symbols to distinguish between a matrix and its determinant, one may wonder where the numbers of the matrix come from. Let us focus our attention on the very first matrix and assume for the sake of the example that we have a production problem which is expressed in the following system of simultaneous linear equations:

$$\begin{aligned}
3x+3y+5z+6u&=8 \\
2x+5y+3z+6u&=9 \\
2x+9y+4z+3u&=5 \\
3x+6y+7z+2u&=9
\end{aligned}$$

It was stated earlier that simultaneous equations can be written in matrix form. Thus, let us reproduce the same equations with several unknown elements in the form of 3 matrices, each representing different segments of the above system of simultaneous equations:

$$\begin{array}{ccccccc}
 & \text{4 columns} & & \text{1 column} & & \text{1 column} \\
\text{4 rows} \left\{\vphantom{\begin{matrix}1\\1\\1\\1\end{matrix}}\right. & \begin{bmatrix} 3 & 3 & 5 & 6 \\ 2 & 5 & 3 & 6 \\ 2 & 9 & 4 & 3 \\ 3 & 6 & 7 & 2 \end{bmatrix} & \times & \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{bmatrix} & = & \begin{bmatrix} 8 \\ 9 \\ 5 \\ 9 \end{bmatrix} \\
 & A & \times & B & = & C
\end{array}$$

To simplify matters, each of the three matrices may be given names, such as *A*, *B*, and *C*. The fact that matrix multiplication is involved is unimportant at this time. How the problem built into such matrices can be solved will be explained subsequently. The above matrices may have been called $A \times X = P$, meaning that P is the product of the multiplication $A \times X$; or they may have been called 4×4 (4 rows and 4 columns) and 4×1, 4×1 (4 rows and 1 column).

Notice that in lieu of x, y, z, and u, the symbols x_1, x_2, x_3, and x_4 are used (substituted) to designate unknown factors. The reason is that we could easily run out of symbols if in a complex problem instead of four unknowns, 20 or more unknown elements were involved. Furthermore, it should be emphasized that certain letters of the alphabet are customarily employed by mathematicians for *specific* purposes. Thus, we often encounter m or n as well as i or j as subscripts. It is sufficient to remember that some of the letters of the alphabet are reserved for certain designations (symbols). To avoid conflicting symbolization, in many instances Greek letters such as Σ (sigma), π (pi), Δ (delta), etc. are used.

Matrices can be added, subtracted, multiplied, and even divided with one another (though the latter is accomplished much easier through multiplication with its inverse, or reciprocal). Hence, the general concepts are pretty much the same as in conventional algebra, but mechanically they are done differently. More will be said about this later.

While the matrices are identified with capital letters of the alphabet, the various elements of the matrix in question will carry the corresponding small letter. Thus, in the example, the first row (3 3 5 6) would be called in a generalized form as $(a_1\ a_1\ a_1\ a_1)$ whereby a would mean that we speak of a specific element of matrix A. The subscripts 1, in turn, designate that we speak of the *first row*. Obviously, the second row of (2 5 3 6) would be designated as $(a_2\ a_2\ a_2\ a_2)$, the third row as $(a_3\ a_3\ a_3\ a_3)$, and so forth in a numerical order.

To identify more precisely about which element of the matrix we speak, it is essential to also indicate the column where the specific number is located. Accordingly, a_{11} would indicate that we speak of the number in the first row and first column of matrix A. If we read a_{34} we would know that we look for it in the 3rd row and 4th column.

It seems apparent that matrix notation differs from normal algebraic notations. Although at this point it may not be entirely clear why, it makes a great deal of sense to use this new kind of notation technique. The mere fact that the previously mentioned four simultaneous equations can be written as $A \times B = C$ (or alternatively, $A \times X = P$) is a tremendous abbreviation.

THE MATHEMATICS OF THE MATTER

Generally speaking the rules are the same, but the way the mathematical computations are carried out will differ in matrix algebra. For instance, neither in matrix algebra nor in the orthodox algebra is it possible to add unlike elements, such as apples and oranges. In that case, however, it was possible to depict the addition in letters indicating that $a+b=c$. When it comes to numbers, only like numbers can be added. Which numbers in two matrices are alike—because there are so many numbers in each row that we may get confused—can be depicted in the subscript as already indicated. For instance, the addition of two 2×4 matrices will appear as illustrated in Fig. G-2.

$$\begin{bmatrix} \enclose{circle}{a_{11}} & a_{12} & \boxed{a_{13}} & a_{14} \\ a_{21} & a_{22} & a_{23} & a_{24} \end{bmatrix} + \begin{bmatrix} \enclose{circle}{b_{11}} & b_{12} & \boxed{b_{13}} & b_{14} \\ b_{21} & b_{22} & b_{23} & b_{24} \end{bmatrix} = \begin{bmatrix} \enclose{circle}{c_{11}} & c_{12} & \boxed{c_{13}} & c_{14} \\ c_{21} & c_{22} & c_{23} & c_{24} \end{bmatrix}$$

$$A \quad + \quad B \quad = \quad C$$

FIG. G-2

The same addition could be written as

$$\begin{vmatrix} \enclose{circle}{4} & 5 & \boxed{6} & 2 \\ 2 & 4 & 5 & 6 \end{vmatrix} + \begin{vmatrix} \enclose{circle}{3} & 1 & \boxed{2} & 2 \\ 2 & 1 & 2 & 3 \end{vmatrix} = \begin{vmatrix} \enclose{circle}{7} & 6 & \boxed{8} & 4 \\ 4 & 5 & 7 & 9 \end{vmatrix}$$

From the encircled and bracketed elements it can be seen that we added only the like elements of the two matrices. All like elements are denoted with identical subscripts. To reiterate, the elements of a matrix will be denoted with small letters of the alphabet, while the matrix itself is labeled in capital letters. The *specific* element is shown with the appropriate subscript.

Because subtraction would follow a similar pattern as the addition, no further elaboration is given. Matrix multiplication, however, is rather tricky in that only rows and columns can be multiplied; matrix division is even more complicated. Therefore, if at all possible, the latter is accomplished via multiplication with its inverse (reciprocal). This is the reason why matrix division

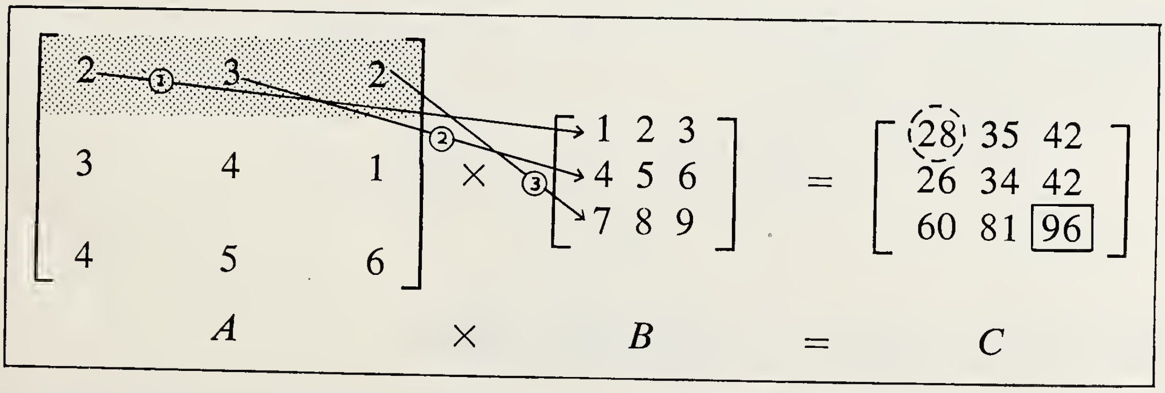

FIG. G-3

will not be explained here. Matrix multiplication is illustrated in Fig. G-3. The first row will be multiplied by the first column as indicated with the 1-2-3 arrows. Thus, (28) is the result of the multiplications: $2\times1=2$, $3\times4=12$, $2\times7=14$, and when all are added up, we get $2+12+14=28$. The second row would, similarly, be multiplied by the second column; the third row, by the third column; and so forth until all the rows and columns were multiplied with one another. In other words,

$$(a_{11}\times b_{11})+(a_{12}\times b_{21})+(a_{13}\times b_{31})=c_{11}$$

$$(a_{11}\times b_{12})+(a_{12}\times b_{22})+(a_{13}\times b_{32})=c_{12}$$

$$(a_{11}\times b_{13})+(a_{12}\times b_{23})+(a_{13}\times b_{33})=c_{13}$$

(Notice that these computations would give the results of row 1 in the above matrix *C*, namely, 28 35 42.) The next step would be to multiply the second row of matrix *A* with the 1st, 2nd, and 3rd column of matrix *B*, and, ultimately, the third row of matrix *A* with the 1st, 2nd, and 3rd column of matrix *B* to get all the elements of matrix *C*. Thus, for instance, to get $\boxed{96}$ in matrix *C* illustrated in Fig. G-3, $(4\times3)+(5\times6)+(6\times9)$ must be added up after the multiplications were performed.

As indicated before, *i*, *j*, *m*, *n*, etc. subscripts are reserved by the mathematician to indicate *rows* and *columns* in generalized formulas. The subscript *i* refers to a *specific* where *m* refers to an *unidentified number* of rows. By the same token, in formulas *j* represents a *specific* column and *n* an *unidentified number of columns*. If the formula wants to depict a rather complex problem with many rows and many columns, it is customary to indicate only the first two elements and the last one as indicated in Fig. G-4.

$$\begin{bmatrix} a_{11} & a_{12} & a_{1j} & \dots & a_{1n} \\ a_{21} & a_{22} & a_{2j} & \dots & a_{2n} \\ a_{i1} & a_{i2} & a_{ij} & \dots & a_{in} \\ \cdot & \cdot & & & \\ \cdot & \cdot & & & \\ a_{m1} & a_{m2} & a_{mj} & \dots & a_{mn} \end{bmatrix} = A$$

Fig. G-4

THE GANTT CHART IN MATRIX FORM

Production scheduling problems in various chapters of this book were depicted in chart form. They can however be reproduced also in matrix form. The machine load chart for instance would, accordingly, list the machines vertically and the time horizontally. In other words, the production program of department A, consisting of two machines, could be expressed as:

$$\begin{pmatrix} a_{11} & a_{12} & a_{13} & a_{14} \\ a_{21} & a_{22} & a_{23} & a_{24} \end{pmatrix} = A$$

or

$$\begin{array}{cc} & \begin{array}{cccc} \downarrow & \downarrow & \downarrow & \downarrow \end{array} \\ \begin{array}{c} \rightarrow \\ \end{array} & \begin{pmatrix} a_{i1} & a_{i2} & a_{i3} & a_{ij} \\ a_{m1} & a_{m2} & a_{m3} & a_{mn} \end{pmatrix} \end{array} = A$$

where $a_i =$ a specific machine in department A;
$a_{ij} =$ a machine a_i per week;
$j =$ specific week (1, 2, 3, 4).

Work may be assigned to a_i machine (ith) during jth week. The vertical arrows point to specific weeks and the horizontal arrow points to specific machines.

MATRIX MANIPULATIONS

It is not feasible within the framework of a brief appendix to give a fully satisfactory explanation as to how figures can be manipulated in matrix algebra. Therefore, it is merely stated that mathematicians found ways and means to reshuffle the figures within the matrix without changing its identity even though each row becomes different. From the explanation in Chapter 15, we know that one can change either side of an equation as long as we do the same thing also to the other side. This maneuver is used, for instance, in the solution of two simultaneous equations in two unknowns. The equations

$$700 = 7a + 21b \tag{1}$$

$$1780 = 21a + 91b \tag{2}$$

can be solved by multiplying Eq. 1 by the number 3. The reason for picking 3 is that by doing so we make $21a$ out of $7a$. As a result, a can be eliminated and we remain with one equation in one unknown. Accordingly, the steps are:

$$700 \times 3 = 7a \times 3 + 21b \times 3$$

or

$$\begin{array}{rcl} 2100 & = & \cancel{21a} + 63b \\ 1780 & = & \cancel{21a} + 91b \\ \hline -320 & = & 0 \quad 28b \end{array}$$

$$b = \frac{-320}{28}$$

$$b = -11\tfrac{3}{7}$$

(Notice that the identity of Eq. 1 has not changed.)

Now that b is known, it can be used in the original equation as a known element. Thus, $7a + 21b = 700$ becomes $7a + (21)(-11\ 3/7) = 700$ and

$$7a - 240 = 700$$

$$7a = 940$$

$$a = \frac{940}{7}$$

$$a = 134\tfrac{2}{7}$$

The above has been reiterated here to illustrate that as long as we changed both sides of an equation, the two sides remained in perfect balance. The same is true in matrix manipulations. Although we change the rows or columns of a matrix, so long as we do not alter the equation, everything remains in balance. Thus, if we want to change any one of the elements of the row matrix (2 10 8 14), to facilitate, for instance, the computation, we can do so as long as we also change all the other elements of the matrix correspondingly. Say, to facilitate the computational work, the first element (first number) of the matrix must be changed from 2 to 1. It is immaterial whether this is attained by dividing the number to be changed by itself (2) or multiplying it with its reciprocal (inverse). The inverse would always place a 1 over it. Thus, the inverse of 2 is ½.[1] In order to maintain the identity of the row, all other numbers in the same row must undergo corresponding changes. This means that every other number must likewise be multiplied with ½. According to this maneuver, the row (2 10 8 14) will be converted to (1 5 4 7).

Why do we *want* to change the 2 in the first row to 1? Apparently, this is done in the interest of solving the problem which the system of simultaneous equations contain. By definition, each matrix has its identity matrix, that is, a matrix where the numbers in the main diagonal are ones, and all other numbers are zeros. If we are able to convert *somehow* the original matrix to an identity matrix, we solve ipso facto the problem which the system of simultaneous equations contained. Therefore, we *want* to change the number in the first row, first column to 1. By the same token, all other numbers must *somehow* be changed to zero. More will be said subsequently about the maneuvers which will permit accomplishing this.

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[1] To invert means to turn it upside down; thus, 2 becomes ½, 3 becomes ⅓, 4 becomes ¼, 5 is converted to ⅕, etc.

According to the above explanation, the following system of simultaneous equations must be converted to change the encircled numbers into 1.

$$\begin{bmatrix} \textcircled{3} & 3 & 5 & 6 \\ 2 & \textcircled{5} & 3 & 6 \\ 2 & 9 & \textcircled{4} & 3 \\ 3 & 6 & 7 & \textcircled{2} \end{bmatrix} \times \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{bmatrix} = \begin{bmatrix} \boxed{8} \\ 9 \\ 5 \\ 9 \end{bmatrix}$$

$$A \times X = P$$

Of course, when we change the one side of an equation, we will also have to change the other side. In other words, any change we make in the numbers of the various rows, we must also make in the solution matrix P. Thus, as we change 3 (encircled) in the first row and the other numbers to zero, we must also change 8 (bracketed) on the other side of the equation correspondingly. This is in line with the rule that whatever we do to one side of an equation must also be done to the other side of the equation.

MATRICES IN SERVICE OF OPERATIONS RESEARCH

Assume that a production problem is expressed in the following system of simultaneous equations:

$$7a+21b=700$$

$$21a+91b=1780$$

This is a simple problem which can be solved either through matrix algebra or through the conventional algebra. With the latter method, the answer to the problem was $a=134\frac{2}{7}$ and $b=-11\frac{3}{7}$. For the purpose of illustrating how the mechanism of matrix application can solve the same problem, let us set up the matrices. We will use an X matrix indicating the unknown elements of a and b. It is more convenient to call the above x_1 and x_2. But more important are the coefficient matrix and the solution matrix. Along with these we will use an identity matrix.

It has already been explained that any row can be changed as long as every element of the same row is proportionately altered. Since the matrices we use represent the same equations as shown above, when we change a row in the coefficient matrix, evidently we must also alter the solution matrix proportionately. Now, the attempt is made to convert the coefficient matrix into an identity matrix; as we gradually change the rows, we are getting step by step closer to the solution. How rows are changed is unimportant as long as the equality of the equation or the identity of the matrix remains unchanged. The above three matrices could be labeled as follows:

$$A \times X = P$$

Coefficient Matrix		Variable Matrix	Solution Matrix	Identity Matrix		Tableau
7	21	x_1	700	1	0	I
21	91	x_2	1780	0	1	
7	21	x_1 ↑	700	1	0	II
0	28	x_2	-320	-3	1	
1	3	x_1 ↓	100	$\frac{1}{7}$	0	III
0	1	x_2	$\frac{-320}{28}$	$\frac{-3}{28}$	$\frac{1}{28}$	
1	0	x_1	$\frac{940}{7}$	$\frac{13}{28}$	$\frac{3}{28}$	IV
0	1	x_2	$\frac{-320}{28}$	$\frac{-3}{28}$	$\frac{1}{28}$	

$x_1 = 940/7 = 134\frac{2}{7}$ $\quad x_2 = -320/28 = -11\frac{3}{7}$

The following method of conversion may be used:

1. Multiply row 1 by -3 and add the product to row 2. The purpose is to make a zero out of 21 in the second row.
2. Divide row 1 by 7 to convert seven to 1, then divide row 2 by 28 to also make that number a 1.
3. Multiply row 2 by -3 and add it to row 1 in order to eliminate 3 by converting it to zero.
4. Via three new matrices (tableaus), the original matrix labeled A (coefficient matrix) was forced into the identity matrix as indicated with shaded matrices in the first tableau and in the fourth one. At the same time, we have the inverse of the identity matrix to check the result (see bottom, extreme right).

THE SIMPLEX METHOD OF LINEAR PROGRAMMING

Among the many linear programming methods used in operations research work, the simplex method can be considered the *workhorse*. In this particular appendix it is singled out for a cookbook type of explanation for the simple reason that the case of the Basic Chemicals Incorporated deals with it. Essentially, Basic Chemicals suggests an efficient routing procedure to the parent organization (Amalgamated Iron and Steel) which would permit the most profitable method of casting (producing) any desired hot metal (ingot) quality. This book is, unfortunately, not the place for an exhaustive explanation, but to understand the nature of the suggestion and to enable the reader to pass judgment on its feasibility, a minimum amount of acquaintance with the simplex method is advisable.

Simplex algorithm (method) differs from the earlier discussion of linear equations because it is applicable where the problem is insoluble with normal algebra. We have production situations where—if and when we express them in equations—the number of equations, including inequalities, in toto are fewer in number than the number of unknowns (variables). The simplex method permits even the solution of problems (of course only if they are linearly related) where we have more unknowns than equations. Therefore, the steps to *optimize* the objective function will differ somewhat from the previous explanation. "To optimize" means here to either maximize or minimize the postulated objective (minimize costs, but, of course, maximize profit).

The first step is, as in any problem for which one assumes linear relations, to express the problem at hand in sets of linear equations. The first expression will always assume a method management would select, had no operations research tool been available. Using this as the point of departure, the simplex method will permit improvements, step by step, on the original plan, until finally the optimum solution has been reached.

SIMPLEX MATRIX

The simplex tableau contains several matrices in the ordinary sense. In the same manner as we have done on page 840, the matrix will be a reproduction of the equations into which the problem is built. The first simplex matrix will represent the first feasible solution. We start with probably a poor solution, but as long as it satisfies all the equations, we can start with it and then improve progressively the value of the result by setting up additional tableaus. What is being done, in effect, is to consider all possible alternatives and selecting the best. At the optimum solution, no change will precipitate further improvements.

The first matrix, as any other matrices, will contain the *objective row,* where we list the factors we want to optimize (cost, profit, output, etc.). Then below this we have the *variable row* where the variables, including the slack variables, are listed. In the Basic Chemicals Incorporated case study, the variables are the various ores at our disposal and the slack variables, each of which is nonnegative, which were introduced to equalize the inequality. Below these two rows, are the *body* and the *identity*. The body contains the coefficients of the unknown factors (in the case at hand, the manganese, phosphorus, and sulfur requirements). The identity contains zeros in general, but contains 1 in the main diagonal for every restriction or equation in the body. The *index row* on the bottom of the matrix is derived from the multiplication of each row entry in the given column by the corresponding numbers in the objective column and by summing all these products (that is, results of the multiplications) for the given column, and subtracting the corresponding objective row. The resulting number, the index number, is entered immediately above the respective column headings to form the index row.

The various columns (*objective, variable,* and *constant*) list the factors bearing the same name. The objective column is composed of the net worth of the variables in the variable column.

Although the steps to make up an index row are carried out for all columns in the body, the identity, and the constant column, they are necessary only in the initial formulation of the problem and need not be repeated once the index row has been determined. *Check column* is used for checking the correctness of the mathematical manipulations in subsequent steps rather than to fulfill any specific function. It can be easily found by adding across each row, starting with the constant column. Numbers in the check column are operated on (manipulated) as if they were a regular portion of the matrix.

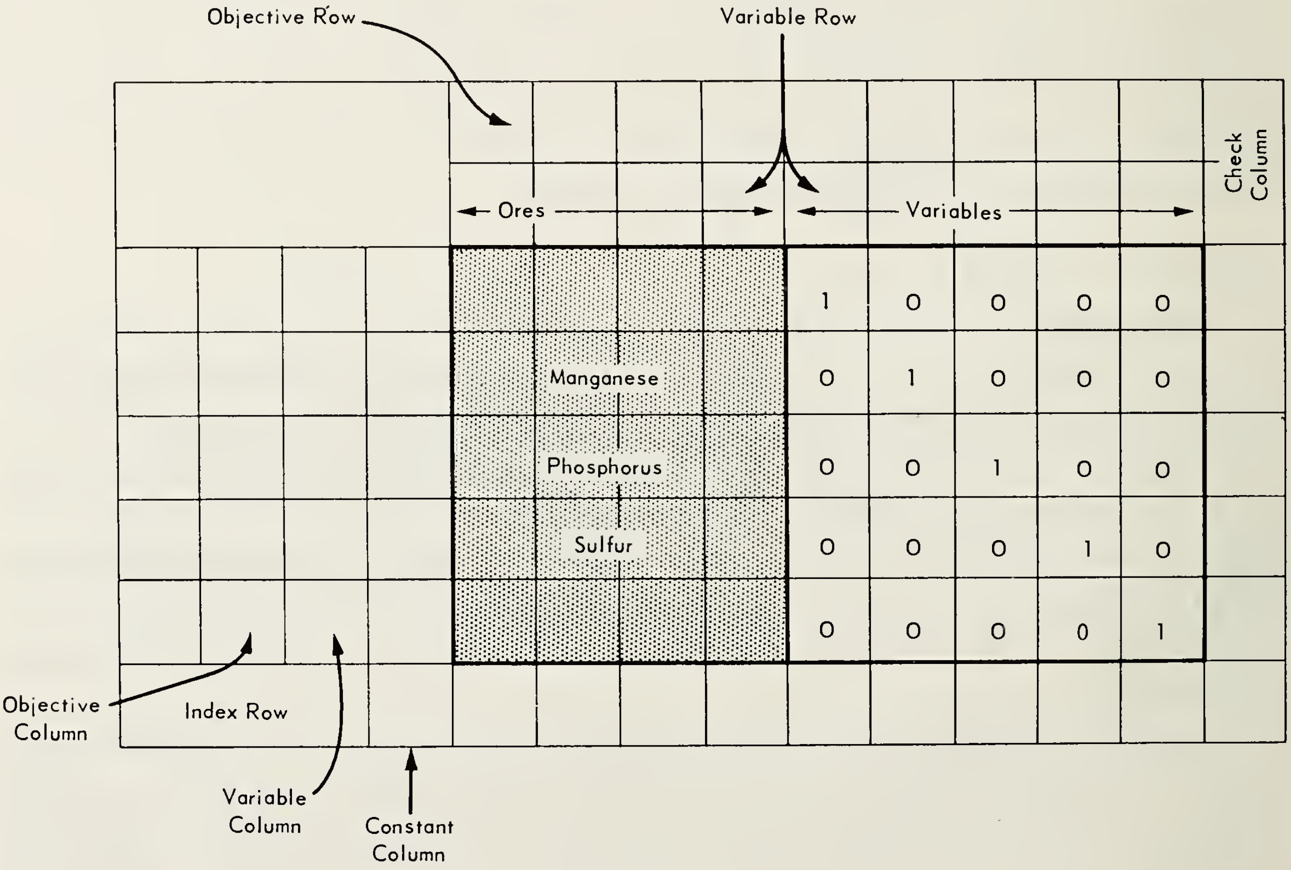

FIG. G-5

Figure G-5 illustrates the construction of the simplex matrix, which, as said before, is a composite of several matrices in the ordinary sense.

Based on the case description, there are four different ores, namely,

O_1 O_2 O_3 O_4. The U_1 and U_2 represent unknowns, in addition to x, y, and z which are the slack variables to make equations out of inequalities. However, they could have been labeled x_1, x_2, x_3, x_4, and x_5.

The simplex matrix in Table 15-17 contains data that represent the first step to the solution of the simplex. All succeeding tables are obtained by repeating a series of steps. These steps can be summarized as follows:

1. Select the most negative number in the index row. Do not include the check column or the constant column in the selection.
2. The most negative number determines the key column.
3. Divide positive numbers in the key column into corresponding numbers in the constant column to yield the quotients (ratios).
4. Select the least positive of these quotients.
5. The row containing the least positive ratio is the key row.
6. The key number is at the intersection of the key row and the key column.
7. Divide the key number into every number in the key row.
8. The quotient of the key row divided by the key number is the main row in the next table.
9. The formula for steps 7 and 8 is

$$\text{Main Row} = \frac{\text{key row}}{\text{key number}}$$

10. All other numbers for the next table are derived by the formula

$$\text{Derived number} = \begin{matrix}\text{selected}\\ \text{number}\end{matrix} - \frac{\begin{matrix}\text{corresponding}\\ \text{number in}\\ \text{key row}\end{matrix} \times \begin{matrix}\text{corresponding}\\ \text{number in}\\ \text{key column}\end{matrix}}{\text{key number}}$$

Repeat steps 1 to 10 until no negative numbers exist in the index row. When no negative numbers exist in the index row, an optimum solution has been obtained. The values that appear in the constant column for each variable represent the optimum solution.

Bibliography

AMERICAN MANAGEMENT ASSOCIATION. "Materials and Methods of Sales Forecasting," *Special Report No. 27*. New York, 1957.

———. "Operations Research," *Special Report No. 13*. New York, 1956.

———. "Operations Research Applied," *Special Report No. 17*. New York, 1957.

APPLE, J. M. *Plant Layout and Materials Handling*. New York: The Ronald Press Co., 1950.

BARNES, R. M. *Motion and Time Study*, 4th ed. New York: John Wiley & Sons, Inc., 1958.

BECKMAN, R. O. *How to Train Supervisors*, 4th ed. New York: Harper & Bros., 1952.

BETHEL, LAWRENCE L., FRANKLIN S. ATWATER, GEORGE H. E. SMITH, and HARVEY, A. STACKMAN, Jr. *Industrial Organization and Management,* 5th ed. New York: McGraw-Hill Book Company, Inc., 1954.

———. *Essentials of Industrial Management*, 2d ed. New York: McGraw-Hill Book Company, Inc., 1959.

BOLZ, H. A., and G. E. HAGEMAN. *Materials Handling Handbook*. New York: The Ronald Press Co., 1958.

BOWMAN, EDWARD H., and ROBERT B. FETTER. *Analysis of Industrial Operations*. Homewood, Ill.: Richard D. Irwin, Inc., 1959.

BRATT, E. C. *Business Forecasting*. New York: McGraw-Hill Book Company, Inc., 1958.

BRIGHT, J. R. *Automation and Management*. Cambridge, Mass.: Harvard University Press, 1958.

BROOM, H. N. *Production Management*. Homewood, Ill.: Richard D. Irwin, Inc., 1962.

BROUGH, B. M."Operational Research as a Staff Service for Management," *Operations Research Quarterly*, Vol. 9 (June, 1958), pp. 126-143.

BROWN, F. R. "Facts about Operations Research; Can Save Time, Costs, Profits," *Management Methods*, Vol. 14 (September, 1958), pp. 39-41.

BUFFA, E. S. *Modern Production Management*. New York: John Wiley & Sons, Inc., 1961.

CARROLL, PHIL. *How Foremen Can Control Costs*. New York: McGraw-Hill Book Company, Inc., 1955.

———. *Time Study for Cost Control*, 3d ed. New York: McGraw-Hill Book Company, Inc., 1954.

CARSON, GORDON B. (ed.) *Production Handbook.* New York: The Ronald Press Co., 1958.

CHARNES, A., W. W. COOPER, and A. A. HENDERSON. *An Introduction to Linear Programming.* New York: John Wiley & Sons, Inc., 1953.

CHORAFAS, DIMITRIS N. *Operations Research for Industrial Management.* New York: Reinhold Publishing Corp., 1958.

CHURCHMAN, CHARLES W., RUSSELL L. ACKOFF, and LEONARD E. ARNOFF. *Introduction to Operations Research.* New York: John Wiley & Sons, Inc., 1957.

CLARK, W. *The Gantt Chart,* 3d ed. New York: Pitman Publishing Corp., 1952.

COWDEN, D. J. *Statistical Methods in Quality Control.* Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1957.

DANO, S., and E. L. JENSEN. "Production and Inventory Planning in a Fluctuating Market," *Operations Research*, Vol. 6 (March, 1958), pp. 293-295.

DAVIS, RALPH CURRIER. *Industrial Organization and Management,* 3d ed. New York: Harper & Bros., 1956.

———. *The Fundamentals of Top Management.* New York: Harper & Bros., 1952.

EILON, SAMUEL. *Elements of Production Planning and Control.* New York: The Macmillan Company, 1962.

ELLIOT, W. W., and E. R. C. MILES. *College Mathematics*, 2d ed. Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1951.

ESHELMAN, R. H. "Can You Profit from Operations Research," *Iron Age,* Vol. 187 (January 16, 1958), pp. 71-73.

EZEKIEL, M., and K. FOX. *Methods of Correlation and Regression Analysis: Linear and Curvilinear.* New York: John Wiley & Sons, Inc., 1959.

FERGUSON, M. "Automation, Key to a More Productive Economy," *Commercial and Financial Chronicle*, Vol. 187 (March 13, 1959), pp. 1158-1159.

FREUND, J. E., and F. J. WILLIAMS. *Modern Business Statistics.* Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1958.

FURGESON, ROBERT O., and LAUREN F. SARGENT. *Linear Programming: Fundamentals and Applications.* New York: McGraw-Hill Book Company, Inc., 1958.

GOETZ, BILLY E. *Management Planning and Control.* New York: McGraw-Hill Book Company, Inc., 1949.

GOLD, BÉLA. *Foundations of Productivity Analysis.* Pittsburgh, Pa.: University of Pittsburgh Press, 1955.

GRABBEE, EUGEN MUNTER, SIMON RAMO, and DEAN E. WOOLDRIDGE. *Handbook of Automation, Computation and Control.* New York: John Wiley & Sons, Inc., 1958.

Grant, E. L. *Statistical Quality Control*, 2d ed. New York: McGraw-Hill Book Company, Inc., 1952.

Grant, E. L., and W. G. Ireson. *Principles of Engineering Economy*, 4th ed. New York: The Ronald Press Co., 1960.

Green, J. L. "Planning to Automate: Why?," *Commercial and Financial Chronicle*, Vol. 190 (August 6, 1959), p. 524.

Greenwald, Dakota U. *Linear Programming, An Explanation of the Simplex Algorithm*. New York: The Ronald Press Co., 1957.

Gutenberg, E. *Grundlagen der Betriebswirtschaftslehre—Produktion,* Vol. I. Berlin, Germany, 1951.

Harrington, J. Jr. "Men and Machines, The Effects of Automation," *Supervisory Management,* Vol. 3 (January, 1958), pp. 59-60.

Hawley, G. F. *Automating the Manufacturing Process*. New York: Reinhold Publishing Co., 1959.

Hempel, E. H. (ed). *Small Plant Management*. New York: McGraw-Hill Book Company, Inc., 1950.

Henrici, Stanley B. *Standard Costs for Manufacturing,* 3d ed. New York: McGraw-Hill Book Company, Inc., 1960.

Ireson, William Grant, and Eugene L. Grant (eds). *Handbook of Industrial Engineering and Management*. Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1955.

Jackson, J. R. "A Computing Procedure for a Line Balancing Problem," *Management Science*, April, 1956.

Jeenel, J. *Programming for Digital Computers*, New York: McGraw-Hill Book Company, Inc., 1959.

Juran, J. M. *Quality Control Handbook*. New York: McGraw-Hill Book Company, Inc., 1950.

Koepke, Charles A. *Plant Production Control*, 3d ed. NewYork: John Wiley & Sons, Inc., 1961.

Landy, Thomas M. *Production Planning and Control*. New York: McGraw-Hill Book Company, Inc., 1950.

Lauden, J. K., and J. W. Deegan. *Wage Incentives*, 2d ed. New York: John Wiley & Sons, Inc., 1959.

Lehrer, R. N. *Work Simplification*. Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1957.

Lundy, James L. *Effective Industrial Management*. New York: The Macmillan Co., 1957.

Lytle, C. W. *Wage Incentive Methods*, rev. ed. New York: The Ronald Press Co., 1942.

MacNiece, E. H. *Production Forecasting, Planning and Control*. New York: John Wiley & Sons, Inc., 1957.

Magee, John F. *Production Planning and Inventory Control*. New York: McGraw-Hill Book Company, Inc., 1958.

MAYER, RAYMOND R. *Production Management.* New York: McGraw-Hill Book Company, Inc., 1962.

MAYNARD, H. B. (ed). *Industrial Engineering Handbook*, New York: McGraw-Hill Book Company, Inc., 1956.

———. "Industrial Engineering," *Encyclopedia Americana*, Vol. XV, Americana Corporation, 1953.

METZGER, ROBERT W. *Elementary Mathematical Programming.* New York: John Wiley & Sons, Inc., 1958.

MOORE, F. G. *Production Control*, 2d ed. New York: McGraw-Hill Book Company, Inc., 1959.

MOORE, J. M. *Plant Layout and Design.* New York: The Macmillan Co., 1961.

MUTHER, R. *Practical Plant Layout*, New York: McGraw-Hill Book Company, Inc., 1955.

McMANUS, G. J. "Steel Pay Rates Meet Challenge of Growing Automation," *Iron Age*, Vol. 181 (March 13, 1958), pp. 61-63.

NIEBEL, B. W. *Motion and Time Study*, rev. ed. Homewood, Ill.: Richard D. Irwin, Inc., 1958.

NIEBEL, BENJAMIN W., and EDWARD N. BALDWIN. *Designing for Production.* Homewood, Ill.: Richard D. Irwin, Inc., 1957.

RAGO, LOUIS J. *Kostensenkung durch Rationalisierung.* Munich, Germany: Verlag Carl Hanser G. m. b. H., 1958.

———. "Operations Research im Industriebetrieb—Zum Problem optimaler Kapazitätsausnutzung," *Zeitschrift für Betriebswirtschaft,* Vol. 32 (issues 7-8, 1962), pp. 402-419. Wiesbaden, Germany: Verlag Th. Gabler.

———. "Anwendung des Operations Research im betrieblichen Wirtschaftsleben," *Unternehmensforschung-Operations Research*, Vol. 4 (Book 2, 1960), pp. 68-79. Würzburg, Germany: Physica-Verlag.

———. "Operations Research, ein neuer Weg zur Lösung alter Probleme," *Rationalisierung*, Vol. 9 (Book 11, 1958), pp. 277-280. Munich, Germany: Carl Hanser Zeitschriftenverlag G. m. b. H.

RÖSSLE, KARL. *Allgemeine Betriebswirtschaftslehre,* 5th ed. Munich, Germany: Verlag Hueber, 1957.

RUSINOFF, S. E. "Gradual Automation," *Management Methods*, Vol. 15, 1958.

SAATY, THOMAS L. *Mathematical Methods of Operations Research.* New York: McGraw-Hill Book Company, Inc., 1961.

SCHLAIFER, R. *Introduction to Statistics for Business Decisions.* New York: McGraw-Hill Book Company, Inc., 1961.

SCHRAGE, R. W. "Optimizing a Catalytic Cracking Operation by the Method of Steepest Ascents," *Operations Research*, Vol. 6 (July, 1958), pp. 498-515.

SIMON, H. A. *Administrative Behavior.* New York: The Macmillan Co., 1957.

SMITH, P. W., and C. E. LOWE. "Operations Research 1958; Today It Can Get Sure Answers to Your Common Shop Problems," *Factory Management*, Vol. 116 (August, 1958), pp. 66-71.

TERBORGH, G. *Dynamic Equipment Policy*. New York: McGraw-Hill Book Company, Inc., 1949.

TIMMS, H. L. *The Production Function in Business*. Homewood, Ill.: Richard D. Irwin, Inc., 1962.

VANCE, STANLEY. *Industrial Administration*. New York: McGraw-Hill Book Company, Inc., 1959.

VÁZSONYI, ANDREW. *Scientific Programming in Business and Industry*. New York: John Wiley & Sons, Inc., 1958.

VILLERS, RAYMOND. *The Dynamics of Industrial Management*. New York: Funk & Wagnalls Company, 1954.

———. *Dynamic Management in Industry*. Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1960.

VORIS, WILLIAM. *Production Control*, rev. ed. Homewood, Ill.: Richard D. Irwin, Inc., 1961.

WAGNER, H. M. "Simplex Method for Beginners," *Operations Research*, Vol. 6 (March, 1958), pp. 190-199.

WALKER, C. R. "Life in the Automatic Factory," *Harvard Business Review*, Vol. 136 (January, 1958), pp. 111-119.

WRIGHT, W. *Forecasting for Profit*. New York: John Wiley & Sons, Inc., 1947.

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